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The Relation Between Interest in Science and Children's Scientific Thinking in Middle to Late Childhood

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Dedication

This dissertation is dedicated to my wife Maggie and the two best boys, Odin and Cuchulain. We finally did it.

ABSTRACT OF THE DISSERTATION

The Relation Between Interest in Science and
Children's Scientific Thinking in Middle to Late Childhood

by

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Doctor of Philosophy, Graduate Program in Psychology
University of California, Riverside, September 2019
Dr. Mary Gauvain, Chairperson

This study examined the relation between 9 and 12-year-old children's interest in science and their scientific thinking skills. Eighty children aged 9 and 12 years and their parents reported their interest in science and children answered epistemological understanding questions and solved scientific reasoning problems during a one-time laboratory visit. In addition, children answered questions concerning their concept of science, their parents' interest in science, and individual factors related to scientific thinking. During the child's participation, their parent filled out demographic, academic achievement, and their own interest in science questionnaires. Findings reveal that children's interest in science and concept of science related to their epistemological understanding, and the relation between children's interest in science and epistemological understanding is mediated by children's critical thinking skills. Results further showed that children's age and academic achievement, but not interest in science, related to their scientific reasoning skills. Other findings revealed that children's identification with science as an interest was the predominant characteristic of interest to relate to epistemological understanding, and that children's interest in science related to children's perception of their mothers as

interested in science. These findings are discussed in relation to their implications for further research and educational implementation.

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Introduction

As public issues, such as whether GMOs are safe to eat or whether recycled water is safe to drink, become more scientifically complex, people will require a proficiency in scientific thinking skills to interpret information from multiple sources and use that information to make decisions regarding these issues (Sinatra & Hofer, 2016). The importance of developing children's proficiency in scientific thinking, in addition to their science knowledge, can be seen in current science education standards. The *analyzing and interpreting data* section of the *science and engineering practices* portion of the *Next Generation Science Standards* (NGSS) emphasizes teaching children reasoning and evidence interpretation skills (Lehrer & Schauble, 2015; National Research Council, 2013). Despite its importance, contemporary research shows that children have difficulty developing scientific thinking skills. A recent report by the Stanford History Education Group (SHEG) found that over 80% of middle school children are unable to differentiate between biased and unbiased science news (Wineburg, McGrew, Breakstone, & Ortega, 2016). People with less-developed scientific thinking skills are more likely to hold anti-scientific beliefs, such as climate change denial and anti-vaccination beliefs, and are more vulnerable to believing false scientific claims they may encounter throughout their everyday lives (Zimmerman & Croker, 2014). Thus, it becomes important to examine factors that may positively relate to children's developing scientific thinking skills and the use of these skills outside classroom situations about real-world issues. To achieve this aim, this dissertation investigated whether children's interest in science, a key motivator for learning about scientific topics (Renninger & Hidi, 2016), and other factors relate to children's scientific thinking skills at ages 9 and 12 years old.

Scientific thinking is a multifaceted construct that is defined as people's intentional gathering of information to be used as evidence, their reflection on this information to evaluate that evidence, and the revision of their prior theories based on such evaluations (Zimmerman, 2007). Children can use their scientific thinking skills to acquire new theories, or revise existing theories, about how the world works. Children's theories are defined by scientific thinking researchers Kuhn and Franklin (2006) as children's beliefs about the biological, physical, and psychological world that children use to organize and comprehend the things they experience. This definition was mirrored in reviews of scientific thinking literature, and so was used for this dissertation (Morris, Croker, Masnick, & Zimmerman, 2012). These skills can improve throughout the lifespan, with significant development in middle to late childhood between the ages of 8 to 13 (Piekny & Maehler, 2013).

An extensive body of research in developmental science has investigated the components of scientific thinking. Prior research has emphasized that scientific thinking is typified by the coordination between children's epistemological understanding and their reasoning skills (Kuhn, 2011). Epistemological understanding is described as children's current conceptual understanding of how their theories about what children observe or believe are related to a specific piece or set of evidence (Kuhn, Cheney, & Weinstock, 2000). Children's scientific reasoning includes the reasoning and problem-solving skills used to generate, test, and revise their prior theories (Zimmerman, 2007).

Children must both possess an understanding of the coordination between theory and evidence, and the skill to utilize this information, to revise or reinforce their theories about the world, make decisions, and solve problems (Zimmerman, 2007).

One gap in the scientific thinking literature is the relation between the development of scientific thinking skills and children's interest in science. Interest in science is defined as one's state of engagement with a topic, level of attention to a topic, and predisposition to voluntarily re-engage with a topic (Renninger & Hidi, 2016). Children's engagement and level of attention during various daily activities, such as reading books or exploring the internet, is influenced by their own personal interest in the activity (Renninger, Ewen, & Lasher, 2002). The high degree of attention and consistency of engagement associated with an individual's higher levels of interest may be particularly important for the development of scientific thinking.

The current dissertation investigated the relation between interest in science and scientific thinking in ages 9 and 12. These ages were chosen because children's scientific thinking skills develop significantly around the age of 10 (Kuhn & Franklin, 2006) and children's interests direct their engagement with activities around the age of 11 (Renninger, 2009). As a guide, I proposed a conceptual model (shown in Figure 1) derived from research from both interest in science (Renninger & Hidi, 2016) and scientific thinking (Kuhn, 2011; Zimmerman, 2007). The model describes how children's interest in science may relate to their epistemological understanding and reasoning skills, while taking into account social factors (e.g., gender, ethnicity, and parent interest), cognitive factors (e.g., critical thinking, academic achievement), and other motivational factors (e.g., self-efficacy) identified in prior literature as related to the development and maintenance of children's interest in science (Archer et al., 2010; Renninger & Bachrach, 2015) and scientific thinking (Kuhn, 2011; Zimmerman, 2007).

I begin by briefly describing the development of children's scientific thinking skills and interest in science, and then integrate prior findings on interest in science to explain how scientific thinking skills may develop in relation to interest-directed action (e.g., actions or activities children engage in because of their interest in the topic of the activity, Renninger & Hidi, 2016). The next section briefly reviews background research on the development of interest in science and scientific thinking. The chapter then describes children's scientific thinking and interest in science in greater detail and explores the relation of other demographic (e.g., gender, ethnicity), social (e.g., parent interest in science, children's perception of parent interest), and individual (e.g., concept of science, self-efficacy, critical thinking) factors to children's scientific thinking and interest. The introduction chapter ends with a description of the current study which investigated whether children's interest in science related to their scientific thinking skills, what characteristics of interest related most strongly to these skills, and whether the relation between interest in science and scientific thinking skills improved with age and other individual differences.

Development of Scientific Thinking Skills

Scientific thinking has been defined as intentional knowledge seeking (Morris et al., 2012) and as a specific type of critical thinking focused on generating ideas and systematically testing them to revise one's knowledge (Willingham, 2007). Scientific thinking skills develop primarily from practice and instruction (Kuhn, 2011), and are strengthened by children engaging in various activities in which children attempt to explore or explain their surrounding world with other people or by themselves (Legare, 2014). According to prior research, people can become proficient in scientific thinking skills at age 12 or early adolescence (Zimmerman & Croker, 2014). However, people demonstrate a wide variation in scientific thinking skills into adulthood, with a substantial percentage of adults displaying ineffective reasoning strategies on scientific thinking tasks (Amsel et al., 2008). The high amount of variation in scientific thinking skills within ages has been attributed to individual experiences with explanation and argumentation (Kuhn, 2011).

Explanation and argumentation have been shown to be important experiences relating to the development of both components of scientific thinking skills (Zavala & Kuhn, 2017). Explaining multiple viewpoints aides in the development of epistemological understanding by helping people acquire richer representations of the evidence supporting such viewpoints and how they relate as young as age 2 to 6 (Legare, 2012). Explanations also aid scientific reasoning by drawing attention to the causal relations between different pieces of scientific information (Lombrozo, 2006). Explanation and argumentation may occur during interest-driven action, and thus interest in science may relate to developing scientific thinking skills.

Development of Interest in Science

The development of children's interests in various topics begins in early childhood, emerging as early as ages 3 to 4, with interests being socially constructed by children's close relations, such as parents (Renninger & Hidi, 2016). Children's interest in science subsequently directs their engagement with activities and topics that are further socially reinforced or discouraged as children participate in social situations and develop their concepts of who can and cannot be involved in science (Rhodes, Leslie, Yee, & Saunder, in press). By age 10, children have begun to include their interests into their self-concepts and use those interests to direct their pursuit of interested topics (Renninger, 2009). Middle to late childhood, specifically the ages between 9 and 12, may then be a period in which both interest in science and scientific thinking undergo significant development (Hidi & Renninger, 2006; Klaczynski, 2006).

Children's interest in science may influence scientific thinking differently at different ages. At ages 12 and above children and adolescents with higher levels of interest pursue science-related activities more persistently than children at age 9. Twelve-year-old children have greater self-awareness of their interests than 9-year-old children, which directs and maintains their engagement with interested topics (Renninger, 2009). Children's interest also directs their behaviors more at 10 and above, when children are able to self-regulate learning and connect content to their self-generated topics of interest (Renninger & Hidi, 2016). This self-directed pursuit of topics in which children are interested might provide children who have a high interest in science with more experiences with scientific thinking skills.

Ages from 10 to 12 appear to be an important age for the development of interest in science. Interest in science appears to be strengthened or weakened significantly between the ages of 10 to 12, during which time children may begin to incorporate their interests in science into persistent science career aspirations or come to view involvement with science as undesirable or unattainable (Archer et al., 2010). Thus, higher levels of interest at age 12 may represent a deeper disposition towards, and greater value placed on, science as opposed to children at age 9, who might hold a generally high opinion of science but not use that interest to further their learning about science.

To summarize, children's interest in science increases the likelihood that children will continually engage with a topic at a high level of attention. This interest starts young and is, in part, socially constructed by the social contexts in which children develop. Interest directs children's self-chosen activities more by age 10 – 11, and interest in science is either strengthened or weakened considerably by age 13. The next section provides a greater description of scientific thinking.

Scientific Thinking

Scientific thinking involves three specific skills: searching for information, interpreting that information, and inferring conclusions (Zimmerman, 2007). These skills are used in hypothesis generation, experimentation, and evidence evaluation. Hypothesis generation involves the exploration of a problem space to construct a test that would differentiate among several hypotheses (Klahr, Fay, & Dunbar, 1993). Experimentation involves producing tests that alter single variables in order to test a person's hypotheses (Kuhn, 2011). Evidence evaluation involves interpreting observed evidence to infer a conclusion (Lehrer & Schauble, 2015). This type of thinking allows people to coordinate multiple pieces of evidence to help them infer causal relations in their environment. Scientific thinking requires epistemological understanding to know the role evidence plays and reasoning to construct an effective strategy to test their theories. Children develop these scientific thinking skills during everyday situations in which they can engage with scientific topics by themselves and with others.

Directed inquiry in the classroom, in which an instructor structures science-based inquiry, self-initiated exploration, in which children explore science topics of their own volition, and parental influences, in which parents encourage or discourage engagement with scientific activities, aid children in developing their scientific thinking skills (Morris et al. 2012). Instances in which children interact with other people, whether directed or self-initiated, can provide background knowledge and cue children into the essential components of scientific tasks that can aid in developing scientific thinking skills (Zimmerman & Croker, 2014). Previous research has demonstrated that parent's understanding of science is related to better understanding and experimentation skills in children between ages 8 and 10 (Osterhaus, Koerber, & Sodian, 2017). In a meta-analysis of child studies utilizing samples from elementary to high school, children who received guidance in scientific thinking learned how to inquire about science and think scientifically more successfully than those engaging only in undirected exploration (Furtak, Seidel, Iverson, & Briggs, 2012). It may be that children of parents interested in science receive such directed guidance about science and gain experience in out-of-school science activities, such as science museums or science fairs, more often than children of parents with little interest in science. These experiences with parents interested in science may help children participate in science-related activities and engage with science topics more often and with greater guidance. This participation may also help children develop scientific thinking skills to a greater extent than children of parents with less interest in science. Therefore, parental beliefs, how children view those beliefs, and how they view science in general may be significant social influences on children's scientific thinking skills in terms of their epistemological understanding and reasoning skills, social factors have been added to the proposed model.

This dissertation focused on the relation between children's interest in science and two components of scientific thinking established as foundational to the development of scientific thinking skills in middle to late childhood. One component is children's epistemological understanding of how theory and evidence are distinct and coordinated (Kuhn et al., 2000). Children must understand that their prior theories derive from evidence they encounter that either supports or refutes these prior theories. The second component is children's scientific reasoning skills that help them use their understanding of evidence to confirm or revise their prior theories in order to solve scientific problems or make decisions (Zimmerman, 2007). These two components of scientific thinking correspond to the recognition that evidence plays an important part of knowledge and the searching and applying of that evidence to revise theories respectively. These scientific thinking skills may relate to children's interests in science. Engagement with scientific activities (e.g., science fair experiments) aids in the development of both epistemological understanding and scientific reasoning (Kuhn, 2011). As interest in science motivates repeated deep engagement with interested topics, interest-driven engagement with scientific topics, whether alone or with others, may relate to the development of scientific thinking skills (for review, see Renninger, Nieswandt, & Hidi, 2015).

In summary, scientific thinking is developed through exploration and directed instruction (Kuhn, 2011). It is composed of children's epistemological understanding (i.e., children's concepts of theory and evidence) and their scientific reasoning (i.e., children's ability to use that understanding to make inferences; Zimmerman, 2007). The next two subsections discuss the two core aspects of scientific thinking, epistemological understanding and scientific reasoning, and their development in greater detail.

Epistemological understanding. A key prerequisite to scientific thinking and understanding scientific claims is an understanding of how science knowledge is acquired and how it is coordinated with evidence (Sinatra & Hofer, 2016). Understanding the basis of knowledge acquisition and justification lets children distinguish between their theories about the cause of something and how the evidence they encounter either strengthens or weakens those prior theories. This distinction forms the epistemological understanding involved with scientific thinking. To think scientifically, children must understand that evidence and theory are distinct from one another, and that theories are strengthened or weakened by the evidence that supports them (Weinstock, Neuman, & Glassner, 2006). If children recognize that their prior theories depend on supporting evidence, they can then revise these theories when encountering new evidence that contradicts them.

Epistemological understanding develops primarily through encountering competing claims or contradictory evidence, and considering multiple viewpoints (Kuhn, 2011). Because of this, epistemological understanding depends on conceptual development of children's abstract concept of what it means to know something (Sandoval, 2018). Recent research with children ages 8 to 10 showed that children's epistemological understanding, and understanding of science as a process of experimentation, guided children's inquiry and their experimentation skills using evidence to test hypotheses (Osterhaus et al., 2017). As such, developing epistemological understanding gives children a conceptualization of how evidence coordinates with prior beliefs to yield science knowledge that creates a foundation for further scientific thinking skills to develop.

Kuhn et al. (2000) lay out a framework of three hierarchical levels of epistemological understanding based on the coordination between subjective claims and objective facts: 1) absolutist, 2) multiplist, and 3) evaluativist. Epistemological understanding develops along a trajectory from absolutist to evaluativist in relation to a person's understanding of how evidence aids one in evaluating claims. A person with an absolutist understanding views all claims as facts that are either correct or incorrect. Facts are externally located and readily discernable – no justification or evidence is needed as absolute facts need only to be reported (e.g., "I think the soup is spicy, therefore it is spicy"). A multiplist understanding inverts this trend by valuing all viewpoints equally regardless of evidential support. Opinions assume equal weight as facts in support of claims, and therefore evidence cannot disprove theories as every theory is valid (e.g., "I think the soup is spicy and you do not, so the soup is both spicy and not spicy"). Those with an evaluativist understanding, the most advanced epistemological understanding, realize that claims require evidence to support them. Opinions and theories can be strengthened or revised depending on the evidence available (e.g., "I think the soup is spicy and you do not. Yet, you have a high tolerance for spice, so the soup is probably somewhat spicy"). As such, children's epistemological understanding begins as absolutist, in which one's evidence is unnecessary because knowledge is external and absolute, and ends at evaluativist, in which one's knowledge is derived and reinforced by distinct evidence. Lower levels of epistemological understanding (e.g., absolutist and multiplist) can hinder scientific thinking by causing people to misinterpret conflicting viewpoints or value unsubstantiated claims as equal to well-supported ones (Sinatra & Hofer, 2016).

***Development of epistemological understanding*.** Previous research with children has examined the development of epistemological understanding in middle to late childhood. Conflicting findings exist in the literature regarding the age in which children develop their epistemological understanding. Some prior research showed that children largely begin to shift from absolutist to multiplist levels around age 10 (Kuhn et al., 2000), while others have shown children exhibiting such changes between the ages of 5 to 6 (Moshman, 2014). Personal experience, however, has consistently been found to be an important aspect in development of epistemological understanding.

Adoption of an evaluativist stance also relies on educational experiences, such as advanced classes, college, or graduate education and therefore does not develop in all domains equally. Higher levels of epistemological understanding develop primarily through dialogues with others in which people must consider multiple viewpoints, such as arguments (Weinstock et al., 2006), and can arise both inside and outside direct instruction (Valle, 2009; Zavala & Kuhn, 2017). These educational experiences can foster epistemological development in younger children. Children age 9 perform better at scientific thinking tasks, such as evidence interpretation and experimentation skills, when they have instruction explaining the relation between evidence and theories as core concepts of science (Osterhaus et al., 2017). Thus, while epistemological understanding shows some age-related trends, there exists significant inter-individual differences in its development (Zimmerman & Croker, 2014). Such individual differences may relate to individual differences in children's activities and engagement with science topics arising from an interest in science that might lead children to engage with multiple viewpoints that foster this understanding.

Epistemological understanding in relation to interest in science. Knowledge of how epistemological understanding develops can be expanded by examining its relation to interest in science. Children who are more interested in science may seek out experiences or activities that provide instruction or practice in coordinating theory and evidence. As children's persistent knowledge-seeking in the topic of interest characterizes higher phases of interest (Hidi & Renninger, 2006), children who possess an interest in science may encounter contesting opinions and contradictory facts more often, and engage with them more thoroughly, than children with less interest in science. Encountering contradictory facts may force children to create explanations as to why one fact may be more accurate than another (Lombrozo, 2006), which might aid in children developing a more evidence-based epistemological understanding. However, while an understanding of the interconnection between evidence and theory is necessary, children must also be able to use that knowledge to solve problems or make inferences, which requires scientific reasoning.

Scientific reasoning. The other component of scientific thinking is the reasoning skills that allow someone to infer conclusions from single or multiple points of evidence (Legare, 2014). Scientific reasoning skills allow children to develop and test hypotheses, examine and interpret evidence, and coordinate evidence to draw valid inferences (Lazonder & Wiskerke-Drost, 2015). Scientific thinking skills require an epistemological understanding of evidence and theory, with reasoning skills helping children apply their understanding of knowledge to solve problems (Kuhn, 2011). People, once proficient at understanding how evidence supports and validates their prior theories or not, can interpret data they encounter as evidence to determine causes for certain outcomes (Kuhn, Arvidsson, Lesperance, Corprew, 2017). An example of scientific reasoning can be seen in prior research with 10-year-old children by Teasley (1995). In the study, children were presented with a game controlling a pretend spaceship that included a button that's purpose was unknown. Children then utilized their scientific reasoning skills to infer how the unknown button affected the spaceship simulation. Children did so by observing the multiple outcomes of pressing the button paired with different other buttons (i.e., developing and testing hypotheses), comparing outcomes to their prior theories of the button's function (i.e., examining and interpreting evidence), and using these comparisons as evidence to infer the general function of the button (i.e., coordinating evidence to draw conclusions).

For children to reason scientifically they must use several skills: encoding information, devising a strategy, and explaining the outcome. First, children must attend to and encode information relevant to uncovering causal relations (Morris et al., 2012), which requires children to explore available information and recognize potentially relevant variables (Klahr et al., 1993). Second, once such information is attended to, children must formulate a strategy that will provide evidence that can determine whether their prior theories are supported or must be revised. Third, children must adequately explain the outcomes of their tests (e.g., the causal relations) to incorporate them into their revised theories (Lombrozo, 2006). For this dissertation, a strategy is defined as a plan of action to effectively answer one or more questions. In terms of scientific thinking, people employ strategies they believe will successfully test their hypothesis. The most efficient strategy used is the control of variables strategy (CVS) in which a person changes one variable while keeping others constant in order to infer causal relations (Jewett & Kuhn, 2016). This strategy is effective as it allows for the direct comparison of two variables while removing confounding sources of evidence.

To examine children's scientific reasoning comprehensively, this dissertation focused on children's coordination of several points of information as sources of evidence, their use of effective strategies to infer a causal relation between variables, and their explanatory justifications for their inference. Therefore, scientific reasoning requires the coordination of complex cognitive processes (e.g., formal reasoning and monitoring one's own information) to employ strategies of testing hypotheses (Klaczynski, 2006). This type of reasoning aids people's ability to construct theories about how the world works and to understand scientific information they encounter.

Children's development of scientific reasoning. Children's scientific reasoning develops throughout the lifespan, with consistent age-related trends from as early as age 4

(Zimmerman, 2007). However, children's reasoning skills significantly develop between the ages of 8 and 13, especially when reasoning about more complex evidence (e.g., partial covariation) or in revising theories based on new evidence (Piekny & Maehler, 2013). Kuhn's (2011) review of scientific reasoning also identifies similar age ranges, between age 10 to age 12, as a time when children significantly develop their reasoning skills.

One explanation for scientific reasoning developing during these ages is that children develop their ability to reflect on knowledge they have acquired and how it applies to current situations beginning at age 10, which aides scientific reasoning (Kuhn & Franklin, 2006). Furthermore, children in early adolescence develop the ability to monitor their own acquisition of new information, termed metamonitoring, and use that to change their prior theories (Klaczynski, 2006). Yet, scientific reasoning also shows large inter-individual differences. Scientific reasoning may develop in middle childhood, between the ages of 8 to 10, or late adolescence, between the ages of 15 to 18, but scientific reasoning tasks remain difficult for many adults (Bullock, Sodian, & Koerber, 2009). The inconsistency with which these skills develop suggests that experience and engagement with reasoning tasks may be central components to developing scientific reasoning. As such, children's interest in science, which motivates them to engage with science topics with greater regularity and complexity, may relate to these individual differences in scientific reasoning skills.

Scientific reasoning in relation to interest in science. Children's interest in science may play a substantial role in the development of their scientific reasoning skills.

Kuhn et al. (2017) showed that a deep engagement in scientific practices by adolescents in grade 10, ages 15 – 16, aided in developing skills to interpret and evaluate evidence for science problems with multiple variables. Connecting scientific reasoning tasks to real-world contexts helped children in 6th to 7th grade, age 11 – 13 years, develop better scientific reasoning skills (Jewett & Kuhn, 2016). Interest in science has been shown to relate to engagement with science topics in various ways (Lin, Lawrenz, Lin, & Hong, 2012), and may therefore relate to the development of children's scientific reasoning skills. Interest in topics helped 13-year-old children retain more information when reading about science (Ainley, Hidi, & Berndorff, 2002), and helped children achieve better grades in school at age 11 (Kim, Jiang, & Song, 2015). Yet, the relation between children's interest in science and their development and use of these scientific reasoning skills when children explore STEM-related topics outside of school (e.g., reading about climate change or recycled water on the internet) and how this influence varies across ages, remains largely unknown.

Interest in Science

Interest in science is a multidimensional variable of one's motivation to engage and reengage with content; it includes cognitive, motivational, and affective components (Hidi & Renninger, 2006). Interest always operates in relation to a specific topic, whether narrow, such as spaceships, or general, such as science, in which children may engage (Krapp & Prenzel, 2011). Children who develop an interest in science also develop related motivational factors, such as a sense of self-efficacy (Renninger & Bachrach, 2015), which is one's perceived ability to accomplish a task or behavior successfully

(Bandura, 1997). Children who are interested in science will usually feel greater confidence in completing scientific tasks, which relates to an increase in their self-efficacy regarding science-related topics. Children who express interest in a topic also generally experience positive emotions when engaging with the topic and search out information about it (Renninger et al., 2015).

The most prominent model of interest, the four-phase model of interest, conceptualizes interest as progressing from temporary and situational interests (e.g., interest that occurs while directly engaging with a topic but quickly dissipates) to persistent and individual interests (e.g., interest that remains consistent over months or years). At higher levels of interest, termed *individual interest* as opposed to *situational interest*, children begin to incorporate their interest into their self-concepts, e.g., someone who sees themselves as a future scientist or as someone interested in science (Renninger, 2009). Interest in science also has long range effects. It has been shown to relate to children's academic achievement at age 13 (Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005) and pursuit of science careers at age 15 (Lin et al., 2012). Additionally, interest in science motivates not just future engagement, but a deep engagement with science activities, defined as a high level of focus on and concentration during an activity, that can potentially lead them to inquire about science issues and explore related science topics (Feinstein, Allen, & Jenkins, 2013).

To summarize, interest in science motivates children to engage with science topics more often, and explore these topics more extensively, it also relates to their self-efficacy in understanding or engaging with science topics beginning in middle school (for review, see Hidi & Renninger, 2006). Therefore, interest may also relate to the development of children's epistemological understanding and reasoning skills related to scientific thinking because it often involves an increased curiosity about science topics and a greater attention to the underlying causes of scientific processes (Renninger & Hidi, 2016). This curiosity and knowledge seeking have been shown to relate to epistemological understanding (Kuhn, 2011) and scientific reasoning (Klahr, Zimmerman, & Jirout, 2011). Furthermore, interest may become especially relevant during the ages 9 to 12 years, which are ages of significant development in scientific thinking (Piekny & Maehler, 2013).

Social factors related to interest in science. The development of children's interest in science adheres to a sociocultural perspective. Primarily, children's interest in science can be conceived of similarly to other cognitive processes, by beginning as externally constructed within the child's social world and becoming internalized cognitive processes through interactions with others (Lawrence & Valsiner, 1993; Vygotsky, 1978). Interest arises from the interaction between the child and both the physical and social environment (Hidi & Renninger, 2006). Children's interest emerges through interactions they have that trigger an interest, which may be supported or inhibited by factors such as other people or gender expectations. For example, parents provide structured interactions with science topics that help foster and sustain children's early phases of interest during preschool and elementary school (Alexander, Johnson, & Leibhan, 2015). If parents do not support children's interest in science, or children feel that science as a topic is socially undesirable (e.g., "only losers or nerds are interested in science") or not applicable to them (e.g., "only boys can do science"), children may not pursue science-related activities that provide the experience and instruction necessary to develop scientific thinking skills. Additionally, according to the developmental niche theory, children can acquire socially valued beliefs or practices when they observe or attend to these practices or beliefs (Super & Harkness, 1986). Children may be more likely to develop beliefs of science and scientific inquiry to be consistent with their parents' beliefs (Valle, 2009). Children's engagement in scientific topics also related to how much parents relate science topics to their own lives (Callanan, Castañeda, Luce, & Martin, 2017). Therefore, parental influence may be strong if children perceive that their parents support the belief that science is interesting or that engaging in scientific activities is worthwhile.

Additionally, a child's interest in science decreases if they view science as either not conforming to their gender or ethnic identities, for example if a child viewed science as exclusively meant for European American boys and men (Rhodes, et al., in press). Children can lose interest in science when they perceive themselves as not being able to be scientists or when they feel that their gender or ethnicity is excluded from social conceptions of *scientists* (Lei, Green, Leslie, & Rhodes, 2019). At ages 11 – 12, girls experience a swift drop in interest in science and pursuit of scientific topics (Renninger et al., 2016). Additionally, non-European American children have significantly more negative attitudes towards science (Osborne, Simon, & Collins, 2003). These gender and ethnic differences are widely found in the literature and may originate from feelings that girls or non-Caucasian individuals are not welcome to engage in science (Archer et al., 2010). Therefore, research on interest as a motivational or predictive factor related to the development of scientific thinking would benefit by considering the influence of demographic factors, such as gender or ethnicity, to examine how they relate to children's interest in science, and subsequently, children's scientific thinking skills.

An interest in science may encourage children to engage more deeply with scientific topics and inquire more about scientific information in ways that foster children's scientific thinking skills (Krapp & Prenzel, 2011). Seeking explanations may aid children's scientific thinking. As such, individual differences in interest may relate more strongly to children's evidence-based epistemological understanding or higher levels of scientific reasoning during these later ages. Thus, children's interest in science may be especially relevant to their development of epistemological understanding, specifically in terms of what knowledge is and how it is used, and their skill at reasoning about patterns of evidence. If children are more interested in science, then they may be more motivated to engage with science-related activities that require the reasoning skills and epistemological understanding to develop scientific thinking. Furthermore, if interest provides an effective avenue for sustained engagement with science learning in ways that aid scientific thinking, interest-based interventions may be especially helpful to educators teaching these important skills. Yet, as interest involves interactions between children and their environment, social factors may also represent key covariates to the relation between interest and scientific thinking.

Though interest may be a key motivational factor to children's development of scientific thinking skills, questions remain as to what part of interest relates to children's scientific thinking skills. Scientific thinking is typified by seeking out knowledge to build upon and revise a person's prior theories about the world, and interest leads people to engage persistently with a topic of interest and learn more about interested topics. However, interest contains multiple characteristics, such as children's positive affect while engaging with a topic or identification with a topic, that might have stronger or weaker relations to scientific thinking. Therefore, this dissertation examined the in-depth characteristics of interest in relation to children's epistemological understanding and scientific reasoning. The next section details the four characteristics of interest in science focused on in this study and how they relate to scientific thinking.

Characteristics of Interest and Their Role in the Development of Scientific Thinking in Middle to Late Childhood

As interest is a multifaceted construct that comprises cognitive, motivational, and affective components (Krapp & Prenzel, 2011), it is important to examine the characteristics of interest in-depth. These characteristics represent the ways children engage with an interested topic (e.g., having fun during science activities or curiously seeking new science knowledge) and view the topic of interest (e.g., that science is a part of their self-concept or that it is an important topic). Prior research has shown that interest involves enjoyment, curiosity, value, and identification that characterize the components of interest (for review, see Renninger & Hidi, 2016). For example, the affective component can be characterized as positive feelings (e.g., enjoyment) when people engage with the topic of interest, while the cognitive aspects can be characterized by children asking curiosity-based questions that delve into deeper aspects of the interested topics or identifying with the topic. Children with different levels of these characteristics of interest may interact differently with topics they find interesting (Dierks, Höffler, Blakenburg, Peters, & Parchmann, 2016), and some may relate to scientific thinking more than others. The current dissertation focused on these four characteristics of interest in relation to science to determine which relate most strongly to scientific thinking, and where educational interventions aimed at increasing scientific thinking and interest may be most effective.

Enjoyment. Enjoyment associated with interest has been related to children's continued engagement with topics of interest at age 13 (Ainley et al., 2002), and with deeper exploration of interesting topics at age 12 – 15 (Azevedo, 2015). Enjoyment is defined as the positive affect children experience while engaging with science activities or topics (Ainley & Ainley, 2011). Additionally, enjoyment has been linked to more hands-on activities and time spent engaged in topics of interest (Renninger & Hidi, 2016). When children enjoy science, they may be more likely to engage with science more deeply and explore different ways to engage with science topics. People who hold positive views of science engage with science inquiries in ways that mirror authentic scientific methods (i.e., finding and using evidence to test hypotheses), and explore new science topics with other interested people (Feinstein et al., 2013). Prior research showed that this deeper exploration-based engagement helped adolescents in 10th grade develop both an epistemological understanding and reasoning skills by giving children experience testing hypotheses and interpreting data (Kuhn et al., 2017).

However, enjoyment of science may relate to children learning about scientific information, but not influence children to seek out deeper explanations that relate to developing scientific thinking skills. Exploration is a central component of scientific reasoning development because it can lead to novel outcomes or counterintuitive findings that must be explained (Legare, 2012), and such explanations require reasoning skills. Yet, children enjoying a scientific topic might not concentrate on the aspects of science related to scientific reasoning, such as hypothesis testing and verification (Azevedo, 2015). For example, children may focus on the size of a chemical reaction instead of what conditions precipitated that reaction. Children focusing on these aspects might not attend to the causal relations and evidence, which are central to scientific thinking (Zimmerman, 2007). Thus, enjoyment may be a potential influence on scientific thinking, but may not draw children's attention to the essential aspects of inquiry related to its development.

Curiosity. One characteristic of people with higher levels of interest is that they seek out and search for information regarding the interested topic and feel rewarded when they do so (Renninger & Hidi, 2016). As scientific thinking requires the intentional seeking of information (Kuhn, 2011), children's curiosity in interested topics may lead them to engage in various components of scientific thinking including knowledge seeking, theory revision, and data interpretation that aid in the development of epistemological understanding and scientific reasoning. Children's interest-related curiosity may also aid in developing children's epistemological understanding by providing children with greater amounts of potentially contradictory evidence that children must coordinate with their prior theories, which aids children in understanding the relations between cause and effect (Lombrozo, 2006). Additionally, curiosity may motivate children to explore a wider range of science topics. This exploration might influence children's scientific reasoning skills by encouraging children to explain outcomes of their searching, which involves drawing inferences from the data they observe (see Legare, 2014, for a review).

Value. Value is defined as the perceived importance and usefulness of science (Bong, 2001). Children who value science as important to know about may pay closer attention to science information when it is brought up and might seek out more science information on their own. Valuing science can lead to an increased engagement and commitment to pursuing and processing scientific information (Renninger & Hidi, 2016). This closer attention and engagement in science may provide situations in which children encounter conflicting information or may motivate children to seek out explanations for science information. However, value of science has shown inconsistent relations to academic achievement (Kim et al., 2015). Prior research with middle and high school students showed that perceived value of science related to engagement with science tasks for multiple reasons, for example a desire to master content or a desire to get good grades (Bong, 2001). Motivations such as grades may require only a memorization of facts, but not the deeper mastery of scientific thinking skills. As such, acknowledging the value of science may motivate people to attend to scientific information, but may not necessarily relate to the seeking of information and engagement with science activities in ways that relate to developing scientific thinking skills.

Identification. Identification is defined as children's thoughts about themselves as related to science and incorporation of science into their self-concepts (Renninger, 2009). This characteristic of interest motivates children's participation and engagement with science topics and might foster scientific thinking. Ten- and 11-year-old children who incorporate their science interest into their self-concept are more likely to participate in scientific inquiry and search out a wider range of science knowledge in pursuit of their interests (Archer et al., 2010). Participation in more complex science activities is especially beneficial because it often includes integrating different sources of knowledge, discussing ideas related to science, and connecting these topics to their everyday life (Krapp & Prenzel, 2011). This type of discussion and argumentation have been shown to aid in developing epistemological understanding and scientific reasoning (Kuhn, 2011). Thus, incorporating an interest in science as a component of identity may motivate greater participation in the types of science activities that subsequently influences scientific thinking.

The relation of these four characteristics of interest to children's scientific thinking remains relatively unknown. The characteristics of interest may relate in different ways to children's engagement with science and make different contributions to the development of scientific thinking skills. These four characteristics may provide a way to foster sustained engagement with science information in a way that promotes a continuing use of scientific thinking skills. As such, these characteristics were examined separately in the dissertation to allow investigation of their unique relation to scientific thinking that may inform parents and educators about successful ways to motivate science learning.

The Current Study

The current dissertation aimed to build on prior research in scientific thinking and interest in science by investigating the development of children's epistemological understanding and scientific reasoning skills in relation to their interest in science and how these relations change in middle to late childhood. The model put forth in this dissertation (see Figure 1) posits that children's interest in science connects to both their general epistemological understanding and their scientific reasoning skills. Furthermore, the model includes demographic factors (e.g., child gender and ethnicity), individual differences of children (e.g., child age, experience with out-of-school science activities, academic achievement, child's concept of science, self-efficacy, general critical thinking, and perception of parent interest in science), and parent factors (e.g., education and interest in science) that may contribute to this relation.

The dissertation investigated three questions. One, do children with high interest in science, compared to children with low interest in science, show greater epistemological understanding and use of evidence when interpreting scientific information? If so, does this relation differ between children 9 and 12-years-old? Two, how do the four characteristics of interest in science (i.e., enjoyment, curiosity, value, and identity) relate to children's scientific thinking skills and do these relations differ for 9- and 12-year-old children? Three, how does parent's interest in science relate to children's interest in science? This dissertation also explored how child gender, ethnicity, scientific self-efficacy, critical thinking skills, concepts of science, and experience with science relate to the child's interest in science and scientific thinking. Answers to these questions have the potential to advance understanding of how children's interests relate to the development of their scientific thinking skills. Clarifying the relation between interest in science and scientific thinking skills may be especially valuable for informing educational practices that seek to foster the development of scientific thinking skills.

Research question 1. The first research question is whether children's interest in science relates to their scientific thinking skills, namely their epistemological understanding and scientific reasoning, and whether this relation is moderated by children's age. The current study addressed the first research question by examining whether children's scientific thinking skills vary by their level of interest in science or age, and tests for interactions between children's age and their interest in science on their scientific thinking skills. There are three hypotheses related to this research question.

Hypothesis 1a. Children younger than 11 years of age do not consistently self-reflect on their own interests, which, in turn, impacts their self-directed behaviors in areas of interest (Renninger, 2009). Additionally, children who remain interested in science past the ages of 10 and 11 years exhibit higher identification with science and pursue scientific activities and careers more often (Archer et al., 2010). Furthermore, scientific thinking tasks are more difficult for children before the age of 10 (Kuhn & Franklin, 2006; Klaczynski, 2011). Therefore, 12-year-old children may be more proficient in scientific thinking tasks than 9-year-old children. As participating in science-related activities is necessary for the development of scientific thinking skills (Kuhn, 2011), and interest directs behavior more for children in older ages, I hypothesize that 12-year-old children will demonstrate more evidence-based epistemological understanding and score higher on scientific reasoning tasks than 9-year-old children.

Hypothesis 1b. As interest in science relates to how well children process science information (Ainley et al., 2002), it may also relate to children's epistemological understanding concerning the coordination of evidence and theory (Weinstock et al., 2006). I hypothesize that interest in science will significantly positively relate to children's epistemological understanding and that this relation will be stronger for 12-year-olds as compared to 9-year-olds.

Hypothesis 1c. As interest in science relates to problem solving (Renninger et al., 2015) and knowledge-seeking behaviors (Hidi & Renninger, 2006), both of which relate to scientific reasoning (Klahr et al., 2011), I hypothesize that interest in science will significantly positively relate to children's scientific reasoning skills and that this relation will be stronger for 12-year-olds as compared to 9-year-olds.

Research question 2. The second research question asks what characteristics of children's interest in science (i.e., enjoyment, curiosity, value, and identification) most strongly relate to the development of these skills and how these characteristics differ in middle to late childhood. The current study addressed the second research question by examining children's epistemological understanding and scientific reasoning in relation to four characteristics of interest in the realm of science and child's age. There are two hypotheses for the second research question.

Hypothesis 2a. All four characteristics of interest in science will be positively related to epistemological understanding and scientific reasoning skills. Positive affect such as enjoyment and value of science increase engagement in tasks (Ainley et al., 2002; Krapp & Prenzel, 2011) that are required for developing scientific thinking skills (Zimmerman, 2007). Additionally, curiosity and identification are characteristics of interest that relate to asking knowledge-seeking questions and experimentation (Renninger et al.,2015) that influences scientific thinking skills (Klahr et al., 2011). Thus, I hypothesize that all four characteristics of interest will positively relate to both epistemological understanding and scientific reasoning and that these relations will appear for both age groups of children.

Hypothesis 2b. Curiosity and identification will show the strongest relation to children's scientific thinking skills because they are more related to seeking information (Renninger & Hidi, 2016). As such, I hypothesize that enjoyment and value will have a weaker relation to children's epistemological understanding and scientific reasoning than identification and curiosity for children age 9 and age 12.

Research question 3. The third research question asks what influence parents have on the relation between children's interest in science and their scientific thinking skills. The current study addressed the third research question by examining the relations between children's interest in science and their parents' interest in science. As this study focuses on out-of-school science thinking, and accurate measures of teacher effects on children rely predominantly on teacher reports over child reports (Alexander et al., 2015), this research does not investigate teacher effects. There are two hypotheses for this research question.

Hypothesis 3a. Parent's interest in science will relate to children's interest in science. Parents provide access to information and regulate activities that can provide opportunities for children to explore scientific topics and encourage learning (Alexander et al., 2015). Therefore, I hypothesize that parents' interest in science will relate to children's interest in science and will do so for both age groups of children.

Hypothesis 3b. Children's perception of parents' interest will moderate the effect of parent interest on child interest. Parents commonly influence children's interest in science through interactions with children about the topic (Alexander et al., 2015). If children do not perceive their parents to be receptive or interested in science, they may be less likely to initiate interactions with parents about science topics. Alternatively, children who perceive parents as receptive or interested in science may initiate interactions more often. As such, I hypothesize that children's perception of parents' interest will moderate this relation for children both age 9 and age 12.

Exploratory analyses. Children's ethnicity, gender, self-efficacy, general critical thinking, as well as their concepts of science and experiences with science, have been shown to influence children's interests in science and scientific thinking skills (Archer et al., 2010; Crowley et al., 2001; Lei et al., 2019). As such, I explored whether these factors emerged as significant covariates in the regression models analyzing the relation between children's interest in science and scientific thinking skills. No age-related pattern was predicted.

Method

Participants

To provide the required power for the main ordinal regression analyses according to G*Power 3, a validated statistical power analysis program (Faul, Erdfelder, Lang, & Buchner, 2007), the study included 80 children 9 years old (n = 40, 50% male, M_{age} = 9 years 5 months, SD = 3.94 months) and 12 years old (n = 40, 50% male, M_{age} = 12 years 4 months, SD = 3.16 months) and their parents. Participants were recruited via the Developmental Psychology Participant Database, an electronic database of families who have expressed interest in participating in psychology studies, and through community and science-related events (e.g., science fair).

The sample included 45.7% European American families, 35.8% Latinx families, 4.9% African American families, 3.7% Asian/Asian American families, 7.4% Multiethnic families, and 1.2% chose not to state their ethnicity. Each child's parent also participated by filling out questionnaires during the child participation. Parents included 76 mothers, one father, and three grandmothers, with 17.3% between 25-34 years old, 49.4% between 35-44 years old, and 32.1% between 45-54 years old. One mother chose not to respond.

Parents were generally highly educated, with 29 (36.3%) having a vocational or some college education, 19 (23.8%) having a four-year college degree, and 27 (33.8%) having a graduate degree. One participant (1.2%) reported some high school experience and four (4.9%) reported a high school diploma as their highest level of education.

Families had medium to high socioeconomic status. Ten families (12.3%) reported family income of less than $30,000 per year, 10 families (12.3%) reported annual family income between \$30 - \$50,000, 24 families (29.6%) reported annual family income between \$50 - \$100,000, and 33 (40.7%) reported annual family income of over \$100,000 per year. Four families (4.9%) chose not to report their income.

Procedure

Each family participated in the study during a one-time psychology lab visit which lasted approximately 1 hour. Figure 2 details the following procedure for both parent and child. The study began with both the parent providing informed consent followed by the child providing informed assent. After informed consent was obtained from both parent and child, the child was shown to a nearby observation room while the parent stayed in an adjacent room and filled out the *Demographics Survey*, *Child Academic Success Survey, Child Science Experience Questionnaire, Your Interest in Science Survey*, *Science Efficacy Survey*, *Science Enjoyment Survey*, and *Child Science Experience Survey* with a trained research assistant.

Once in the observation room, the child participant was interviewed by the primary investigator about their general concepts of science (see Appendix A) and perception of their parents' interest in science (see Appendix B). If children provided vague or uninformative responses, the investigator probed children's responses with follow-up questions. Following the interview, the child participant was provided with a pencil and paper, and completed the *Children's Science Topics Survey* (see Appendix C), the *Child Interest in Science Questionnaire* (see Appendix D), the *Self-Efficacy Questionnaire* (see Appendix E), and the *Critical Thinking Survey* (see Appendix F), upon completion children were offered a one to five-minute break and a snack with water. Once children completed the paper questionnaires, the experimenter provided children with a touchscreen laptop to complete the *Jaime and Terry Questionnaire* (see Appendix G) to assess their epistemological understanding. Upon completing the *Jaime and Terry Questionnaire*, child participants were offered another short one to five-minute break, and a snack with water if the child did not accept the first offer of a snack. After the break, child participants were asked to complete a scientific reasoning task (see Appendix H).

For the scientific reasoning task, child participants identified a variable causally related to an outcome when paired with two noncausal variables for two problems, finding out what variable causally relates to clean water and what variable causally relates to livable planets. The primary investigator explained that he wanted to find out what things make a difference to some outcome (e.g., clean water or livable planets) and requested the child's assistance in discovering them. Children were then provided with eight graphs showing either water or planets for the first problem. The two problems were counter-balanced to avoid any rank-order effects. Before beginning, the primary investigator explained the graphs with an example related to healthy versus sick children. The child was then asked to find something that makes a difference to the outcome (i.e., a causal factor) and to inform the investigator once he/she found one. The child participant was given a chance to ask any questions and then allowed to begin. Once the child began the task, the investigator then moved to a different table and pretended to work until the child indicated he/she had found a causal variable. When the child indicated he/she had found a potentially causal factor, the investigator interviewed the child to assess the quality of the reasoning the child used to explain and justify his/her conclusion and to investigate the level of children's scientific reasoning. After the first problem, the primary investigator stated he had another problem he would like the child to help with and introduced the second problem following the same instructions as the first problem. After the second problem was completed, children were congratulated on his/her assistance and were interviewed about the task variables (see Appendix I). After the post-task interview, children were debriefed, thanked, and given a small prize as appreciation. Parents were thanked, debriefed, and compensated $15. Parent and child were then dismissed.

Measures and Materials

The measures and materials used in this dissertation are detailed below. Full lists of items and detailed description of tasks can be found in the appendices. To see where each measure applies to the proposed model, see Figure 3.

Child Measures

Children's concept of science. To evaluate how children conceptualize the word "science" and what scientific thinking entails, children's conceptual understanding of science in relation to testing hypotheses was measured by a short semi-structured interview adapted from research by Sobel and Letourneau (2015). The interview was conducted by the primary investigator. The interview consisted of three interview questions (e.g., "What do you think 'science' means?", "Can you think of a time you did science?", and "What else could be 'science'?"), each containing two follow-up questions (e.g., "if you had to guess, what would you say?", "What does it mean to do something scientific?", "What made that 'science'?", and "What are some other ways you can do 'science'?"), for a potentially 9-item interview. See Appendix A for a full list of items. An open-ended interview was chosen to gather information about children's conceptions of science in their own words while not constraining or influencing their potential responses (Archer et al., 2010). Two independent coders achieved excellent reliability (r = 1.0) on 20% of the sample.

Children's perception of parent interest in science. Children's perception of their parents' interest in science was measured with a 7-item structured interview created for this dissertation. In the interview, children were asked whether they speak with their parents about science or science-related topics. If the child responded yes, they were asked which parent (e.g., mother, father, or both) they talk to, and how often such talks occur (e.g., "a lot" or "a little"). The investigator then asked whether the child thought their parent is interested in science, and the extent to which the parent is interested (e.g., "a lot" or "a little"). The primary investigator asked these items about both parents unless the child indicated only having a single parent. For a detailed list of the interview see Appendix B.

Science topics survey. To assess whether children's interest in science is specific to only a few science topics or in many science topics, the breadth of science-related topics in which children are interested were measured with a survey list of 24 science topics and 4 non-science topics (e.g., video games or healthy eating). This survey was adapted from Bathgate, Schunn, and Corenti (2014), and informed by prior multi-national research investigating science topics children find interesting (Baram-Tsabari, 2015;

Baram-Tsabari & Yarden, 2009). Science topics were presented in a single list and children were instructed to select the topics they would be interested in learning more about. The number of topics children reported having an interest in was summed to determine whether they are interested in a variety of science topics, or if their interest is more focused on specific topics within science. For a full list of topic items see Appendix C.

Interest in science questionnaire. Individual differences in children's interest in science were assessed with a 35-item questionnaire. The measure assessed their general interest in science and four characteristics of interest in science: enjoyment, curiosity, value and identification with science. This measure combined subscales from prior research investigating interest in general to provide more in-depth examination of children's interest in science. Specifically, the subscales were adapted from prior research in interest in general (Marsh et al., 2005) and characteristics of curiosity and identification (Bathgate et al., 2014), enjoyment (Ainley & Ainley, 2011; Pekrun et al., 2011), and value of science (Bong, 2001). Children were asked to respond with the extent to which they agree with each statement (e.g., *I think like a science type person*) on a 5-point Likert scale (1 = *NO!*, 5 = *YES!*). The *NO!* to *YES!* terminology was chosen in order to maintain fidelity with the prior measures as it was the terminology used in most of the subscales (Ainley & Ainley, 2011; Bathgate et al., 2014; Pekrun et al., 2011). Children's average score was used to indicate their overall interest in science, and the average score in each subscale was used to indicate the level of the four characteristics of children's interest. The measure had excellent reliability (Cronbach's $\alpha = 0.94$). For a full list of the measure and subscales see Appendix D.

Child self-efficacy questionnaire. Children's science self-efficacy was measured using a 5-item self-report measure (Bong, 2001). Children were requested to indicate their confidence in each statement (e.g., *I can understand even the hardest material in science if I try*) on a 5-point Likert scale (1 = *Not at all true*, 5 = *Very true*). The average score across all items was used to indicate children's science self-efficacy. The measure had acceptable reliability (Cronbach's $\alpha = 0.73$). For a detailed list of items see Appendix E.

Child critical thinking questionnaire. Children's critical thinking as it pertains to media was assessed with 9-item self-report questionnaire adapted from (McLean, Paxton, & Wertheim, 2016). Media was chosen as it is a difficult context for children to utilize scientific or critical thinking (Wineburg et al., 2016). Children were requested to report how often they performed critical thinking activities (e.g., *I try and think about how true or false an advertisement is*) on a 6-point Likert scale (1 = *Never*, 6 = *always*). The average score across all items was used to indicate the child's general level of critical thinking. The measure had great reliability (Cronbach's $\alpha = 0.81$). For a detailed list see Appendix F.

Epistemological understanding assessment. Children's epistemological understanding was assessed using the *Jaime and Terry Questionnaire*, composed of 12 short vignettes about disagreements between two people named Jaime and Terry. The names were changed from those in the original measure, Robin and Chris, to be gender neutral. This measure was adapted from Kuhn et al (2000), and the vignettes and questions were presented on a computer in random order. A text box displayed the disagreement vignette (e.g., *Jaime believes one explanation for how the brain works. Terry believes a different explanation for how the brain works*), beneath which a multiple-choice question appeared. The question asked children *Can only one of their views be right, or could both have some rightness?* with responses indicating either *only one right* or *both could have some rightness*. If children respond that both could have some rightness, then a follow-up question appeared asking *whether one could be better or more right than the other*. The question had potential responses of *one could be more right* or *one could NOT be more right than the other*. The second question only appears if the child selected *both could have some rightness* in the first question. The wording of the questions follows that used by Kuhn et al. (2000) to maintain fidelity to the original measure.

The measure covered several domains to examine children's epistemological understanding regarding different domains of knowledge, such as physical science and social truths, to construct a general view of children's epistemological understanding. Each domain contains three vignettes to compile a predominant epistemological understanding for that domain. For a detailed list of vignettes see Appendix G.

Scientific reasoning task. A modified version of a scientific reasoning task used by Jewett and Kuhn (2016) was used to assess children's scientific reasoning. The task was modified in four ways. One, the original task focused on crime statistics, and the task used in this dissertation focused on water quality and planets. Two, the original task required children to find a causal and non-causal variable and this task required children to find only a causal variable to simplify the task. Three, the original task included one outcome variable and four potentially related variables, and this task included three potentially related variables to reduce task demands. Four, the original task had only one problem (crime), and this task involved two distinct problems (water and planets). Otherwise the task is the same as in the prior research as it required students to use several records of evidence to come to a conclusion and justify their conclusion to the primary investigator. The task measured the three indicative skills of scientific reasoning: creating a hypothesis, interpreting data, and explaining outcomes. Children must construct a hypothesis to generate a comparison to test. Children must then interpret the data to find a causal factor. Children must then use that interpreted data to infer an outcome and explain it. The task involved two phases, an search for evidence and a semi-structured interview.

The primary investigator began the task by telling the child that the investigator is working with cities to find out some outcome (e.g., what makes water dirty or clean, or what makes a planet livable or unlivable). The investigator then requested the child's help to find out what might make a difference to the outcome. The task included 16 large laminated index cards (eight for each problem), with each displaying three variables and an outcome accompanied by a visual representation (e.g., water drop or planet), see Appendix H for an example of the graphs used. The water problem included the amount of rain, number of pets, and number of factories. The planet problem included the amount or air, number of volcanoes, and number of moons. Each variable was dichotomous as either “high” or “low” and outcomes were also dichotomous (clean or dirty for water, livable or unlivable for planets). Only one variable was causally related to the outcome (water: amount of rain, planets: amount of air). Eight graphs were chosen to provide every combination of “high” and “low” across the three variables. The problems were counter-balanced to account for order effects. For detailed instructions of the task and interview questions see Appendix H.

Upon finding a potentially causal variable, the child notified the primary investigator that they had completed the task. The primary investigator then conducted a 9-item semi-structured interview to examine the child’s justification for choosing the variable. In the *Scientific Reasoning Semi-Structured Interview* (SRSI), the child was asked whether they believe the factor to be causal (e.g., “*does that make a difference?*”) and to explain the evidence used to make this judgment (e.g., “*how do you know?*”). If the child produced a confounded or uncontrolled comparison as justification (e.g., a comparison in which more than one variable changes), the investigator probed for an alternative explanation (e.g., “*What if it is not* [chosen variable], *but* [alternate variable] *instead?*”). If children provided a controlled comparison as justification, the investigator prompted the child to infer a conclusion from their evidence (e.g., “*if someone came up and said they wanted to deal with* [chosen variable] *to make the water cleaner, what would you say to them?*”). The child was then asked about whether the variable they chose was good or bad. Children’s responses to the SRSI was coded to indicate their level of scientific reasoning skills. Two coders obtained excellent reliability (r = 0.98) on 30% of the sample.

The child's epistemological understanding was further explored by saying that another child had stated that an alternative variable (one not chosen by the child) was causal, whether they could be right also, and whether they could be more or less right than the child. For the detailed post-task interview questions see Appendix I.

Parent Measures

Demographic variables. Demographic information (e.g., ethnicity, gender, age) as well as education level, occupation, and socioeconomic status were collected from the child's parent. Other variables such as child's school and grade level were measured to account for these variables and allow for their use in analyses. Previous research suggests that these factors may relate to children's interest (Archer et al., 2010; Renninger et al., 2015). The demographic survey can be seen in Appendix J.

Child's science experience. Children's experience with out-of-school science activities were measured with a parent-report survey. The survey was adapted from the *Video Game Questionnaire* used in Anderson and Dill (2000) and modified in two ways. One, items in the measure were changed from asking about brands of video games and frequency of play to items asking about types of out-of-school science activities and frequency of engagement. The types of activities listed are science fair, science museum, science camps, at-home science activities, science-related TV, and science-related websites. Two, the Likert scale point 1 was changed from *rarely* to *never* to provide a point for parents to signify the child does not participate in the activity. In the first item, parents were instructed to indicate the science-related activities in which their child participates with *yes* or *no* responses. In the second item, were instructed to rate the frequency of children's involvement in the chosen activities on a 7-point scale (1 = *Never* to 7 = *Often*). Children received a single score representing the average frequency of involvement across the five activities that indicates the child's out of school science experience. The measure had low reliability (Cronbach's $\alpha = 0.53$). The items for this measure can be seen in Appendix K.

Child's academic performance. Children's academic performance was assessed with a 5-item parent-report measure. Parents were asked to indicate their child's most recent grades in social science, mathematics, reading, writing, and overall grades to the best of their abilities from the child's homework, report cards, and test scores. Responses were on a 5-point scale (1 = *F* to 5 = *A*). This measure was created for this study, and it is based on parent-reports to avoid potentially influencing children's self-efficacy or other self-perceptions that might confound their responses (Lei et al., 2019). Parent-reports were also used because, as the study was a laboratory visit, teacher-reports were unavailable. Parents' responses were the averaged across all subjects to provide one score for children's academic achievement. The measure had acceptable reliability (Cronbach's $\alpha = 0.78$). The survey items for this measure can be seen in Appendix L.

Parent interest in science. To assess the social factor of parent interest in relation to child interest in science, parents' interest in science was measured by a 3-item self-report survey adapted from prior research (Takahashi & Tandoc, 2016). The parent measure is different from the child measure, as this survey is more directed towards adults, while the child questionnaire is directed towards children. Parents reported their interest on a 3-point scale (1 = *not at all interested*, 2 = *moderately interested*, and 3 =

very interested) in three science topics: space exploration, new science discoveries, and new technology. The average rating across the three topics was used to indicate the parent's interest in science. The measure had lower reliability (Cronbach's $\alpha = 0.58$). The survey items for this measure can be seen in Appendix M.

Parent science efficacy and enjoyment. To explore other motivational factors and characteristics of parent interest, parent science efficacy and enjoyment were also assessed. The measures were adapted from prior research (Wartella, Rideout, Lauricella, & Connell, 2014). Parents reported their general efficacy and enjoyment of STEM topics on a 5-point scale (1 = *Strongly Disagree*, 2 = *Disagree,* 3 = *Neither Agree nor Disagree*, 4 = *Agree*, 5 = *Strongly Agree*) measuring their overall enjoyment of science when they attended school and at the time of the study. Parents received two scores, one computed with the average rating across all nine efficacy items and one computed with the average rating across all six enjoyment items. The measures are reliable for self-efficacy (Cronbach's $\alpha = 0.83$) and enjoyment (Cronbach's $\alpha = 0.86$). A detailed list of items can be seen in Appendix N.

Coding

Below, I describe the coding for the child interviews (the *Child Science Interview*, *Child Perception of Parent Interest Interview*, and *SRSI*), and the epistemological understanding assessment (*Jaime and Terry Questionnaire*). All coding schemes for the variables discussed below are detailed in Appendix O.

Child's concept of science. Children's responses to the *Child Science Interview* items were coded to assess children's conceptualization of science. The measure was coded on a 4-point scale from 0 (*no response*) to 3 (*process*). Each child received one score ranging from 0 to 3 which reflects his or her conceptualization of science as focusing on concrete facts or testing of ideas and hypotheses (Sobel & Letourneau, 2015). Responses were coded as *no response* when children were unable to define or describe science and experiments (e.g., "*I don't know*"). Responses were coded as *identity* when children defined or described science and experiments as simply being science or science class (e.g., "*science is what you do in science class.*"). Responses were coded as *content* when children defined or described science and experiments as the actual activities one does during scientific activities (e.g., "*science is when you run electricity through a potato and light up a lightbulb*"). Children's responses were coded as *process* when children defined or described science and experiments as using some process or strategy to find answers to questions (e.g., "*science is when you have an idea, and you do things to find it out*"). Children's scores were coded on an ordinal scale from zero to three, with 0 = *no response*, 1 = *identity*, 2 = *content*, and 3 = *process*.

Child's perception of parent interest in science. Children's responses to the *Perception of Parent Interest Interview* items were coded to assess children's perception of their parent's interest in science topics. This measure was coded on a 3-point scale from 1 (low) to 3 (high). Responses that showed children talk to neither parent about science topics or, if children do talk to their parents, parents are perceived as being uninterested in science are coded as (1) *low*. Responses that showed children talk to parents at least "a little", and that parents are perceived to be interested in science "a little" are coded as (2) *moderate*. Responses in which children reported talking to their parents “a little” or “a lot” and that their parent is perceived to be interested in science “a lot” are coded as (3) *high*. Children’s responses were used to indicate their perception of parents’ level of interest in science. If children reported speaking to more than one parent, the two parent scores were summed to indicate the total level of parents’ perceived interest in science. Children received one score measuring how much they perceive their parents as interested in science, ranging from 1 to 6.

Child’s epistemological understanding. Children’s epistemological understanding was coded according to Kuhn’s model of *absolutist*, *multiplist*, and *evaluativist* levels used in prior research (Kuhn et al., 2000; Weinstock et al., 2006). This code assessed epistemological understanding on a 3-point scale, ranging from 0-2, to allow for statistical analysis. Children’s responses indicating that only one person can be right were coded as (0) *absolutist*, representing an over- reliance on perceived ‘objective facts’ at the expense of considering opposing viewpoints. Children’s responses indicating that both people could have some rightness, but neither could be more right than the other, were coded as (1) *multiplist*, reflecting a dominance of subjective opinions and neglect of objective facts. Children’s responses indicating that both people could have some rightness, and that one could be more right than the other, were coded as (2) *evaluativist*, reflecting an acknowledgement that subjective opinions are supported by objective facts.

Children’s epistemological understanding in each domain were coded according to the level which they predominantly reported. For example, in the aesthetic domain, if a child responded at an *evaluativist* level for two out of the three questions, they were coded as (2) *evaluativist* for the aesthetic domain. To maintain consistency with prior research (Kuhn et al., 2001), if children responded at different levels to all three items, they were coded at the (1) *multiplist* level. Scores in each domain were summed to indicate their general level of epistemological understanding. If a child responded predominantly (0) *absolutist* in one domain, (1) *multiplist* in two, and (2) *evaluativist* in one, he or she received a score of 4. Each child's scores across all domains were summed into a single epistemological understanding score between 0 and 8.

Child's scientific reasoning level. Children's SRSI responses were coded on a 6-point ordinal scale ranging between level 0 and level 5 to assess how children infer conclusions from multiple sources of data and justify these inferences with evidence (Jewett & Kuhn, 2016). *Level 0* was coded when children were unable to find a causal relation or justified their conclusion only with their prior theories and without reference to evidence. *Level 1* was coded when children justified their conclusions with a single uncontrolled case or incorrect interpretation of several cases. *Level 2* was coded when children justified conclusions with an uncontrolled comparison of two cases and did not acknowledge alternative explanations. *Level 3* was coded when children justified their conclusions with an uncontrolled comparison but acknowledged an alternative explanation. *Level 4* was coded when children provided a controlled comparison but drew inconsistent interpretations of data. *Level 5* was coded when children provided both a controlled comparison and consistent interpretation of the data. Children's performance across both problems was summed to produce one score representing their level of their reasoning skills. The epistemological assessment in the post-task interview was coded according to the *absolutist* to *evaluativist* scheme detailed in the *Jaime and Terry questionnaire* described in detail above.

Results

This dissertation was designed to investigate the relation between children's interest in science and their scientific thinking skills and how this relationship changes in middle to late childhood. To achieve this goal, five sets of variables were assessed: children's age, children's interest in science, children's scientific thinking skills (i.e., epistemological understanding and scientific reasoning), children's individual factors (i.e., children's self-efficacy, critical thinking, academic achievement), and children's social factors (i.e., parent's interest in science, children's perception of parent's interest in science, demographic variables). The following sections reiterate this dissertation's hypotheses and the analyses used to test those hypotheses before moving on to reporting the results of the study in response to each hypothesis. This dissertation had seven hypotheses in addition to exploratory analyses. Following are the primary hypotheses, also presented at the end of the introduction chapter.

- *Hypothesis 1a.* Children will show higher levels of epistemological understanding and scientific reasoning at age 12 than at age 9 (H1a).
- *Hypothesis 1b.* Children's interest in science will have a significant positive relation to children's epistemological understanding and this relation will be significantly stronger at age 12 than at age 9 (H1b).

- *Hypothesis 1c.* Children's interest in science will have a significant positive relation to children's scientific reasoning and this relation will be significantly stronger at age 12 than age 9 (H1c).
- *Hypothesis 2a.* The four characteristics of children's interest in science (i.e., enjoyment of science, curiosity with science, value of science, and identification as science-minded) will have a significant positive relation to children's epistemological understanding and scientific reasoning and will not differ by age (H2a).
- *Hypothesis 2b.* The characteristics of curiosity and identification will show a stronger relation to children's epistemological understanding and scientific reasoning than the characteristics of enjoyment and value and this pattern will be similar at age 12 and age 9 (H2b).
- *Hypothesis 3a.* Children's interest in science will have a significant positive relation to parent's interest in science at both age 12 and age 9 (H3a).
- *Hypothesis 3b.* The relation between children's interest in science and parent's interest in science at both age 12 and age 9 will be moderated by children's perception that their parents are interested in science (H3b).
- We also explore what factors act as covariates in the relation between children's interest in science and their scientific thinking skills (i.e., their epistemological understanding and their scientific reasoning).

Plan of Analysis

To begin, I computed intercorrelations for the main dependent variables to uncover potentially significant covariates to include in the main analyses. To explore the potential effects of social factors (e.g., gender and ethnicity) and individual child factors (e.g., concept of science, self-efficacy, and critical thinking), I examined whether these factors had significant relations to children’s epistemological understanding or scientific reasoning. If significant correlations were found, any significant covariates were added in the models used to test the above hypotheses.

To test H1a, I compared 9-year-olds' and 12-year-olds' epistemological understanding and scientific reasoning scores with independent-samples *t*-tests. If age differences were found, age was included as a predictor in the ordinal regressions used to test H1b and H1c. Because interest in science falls after age 10 (Renninger & Hidi, 2016), interest in science might represent a stronger engagement with scientific topics at age 12 than at age 9. Therefore, if age was a significant predictor in the model, I computed a moderation analysis with age as a moderator variable. If not, I examined the potential main effects for age in the ordinal regression models.

To test H1b, I used an ordinal regression with children’s epistemological understanding as the dependent variable and children’s interest in science as the main predictor variable. If age differences were found, age was also included as a predictor variable. I also included all variables related to children’s epistemological understanding as covariates in the model.

To test H1c, I used an ordinal regression with children's scientific reasoning as the dependent variable and children's interest in science as the main predictor variable. If age differences were found, age was also included as a predictor variable. I also included all variables related to children's scientific reasoning as covariates in the model.

For tests of H1b and H1c, if any covariates showed significant relations to both children's interest in science and either component of scientific thinking (i.e., epistemological understanding or scientific reasoning), I computed a post-hoc regression to explore potential mediation effects. The ordinal regressions were analyzed with Wald tests. Wald tests are commonly used tests to assess the significance of variables in regressions with categorical or ordinal variables and can be interpreted similarly to a chi-squared test (Cohen, Cohen, West, & Aiken, 2003).

To test H2a, I computed another ordinal regression similar to the test for H1b and H1c but with the interest variable separated into its four characteristics (i.e., enjoyment, curiosity, value, and identification) and entered into the model simultaneously as individual predictors. To test H2b, I computed another ordinal regression similar to the test for H1c, but with the interest variable separated into its four characteristics (i.e., enjoyment, curiosity, value, and identification). To understand the strength of each characteristic relative to the others, all four characteristics were entered into the model simultaneously. If age differences were found for any of the outcome variables, age was included in the analyses, if no differences were found, age groups were collapsed for the analyses. If children's interest in science was not a significant predictor in either regression model testing H1b or H1c, the characteristics of interest were not separated for that regression model.

To test H3a, I computed a linear regression with children's interest in science as the outcome variable and parent's interest in science as the main predictor variable. Because children's beliefs about science are influenced by socially valued practices and beliefs in others (Super & Harkness, 1986) and children's perceptions of science relate to their interests in science (Osborne et al., 2003), parents' influence may be stronger if children perceive their parents to be interested in science. Therefore, I computed a moderation analysis to test H3b with children's perception of parents' interest as a moderator variable. If H3a was not supported, I conducted exploratory analyses to investigate any potential main effects of children's perception that their parents are interested in science on children's own interest in science. If age differences were found for any of the outcome variables, age was included in the analyses, if no differences were found, age groups were collapsed for the analyses.

Descriptive Analyses

Children showed a moderate interest in science, (M = 3.63, SD = 0.59), and parents reported a generally high interest in science, (M = 2.42, SD = 0.44). See Table 1 for the means and standard deviations for the continuous variables. Children showed a generally advanced epistemological understanding, with the predominant level of epistemological understanding being a mixture of *multiplist* and *evaluativist* understanding. Children also largely exhibited either a high or low level of scientific reasoning, either being successful on both problems or unsuccessful on both problems. See Table 2 for the frequency distributions of ordinal variables.

Exploratory Analyses

To test for potential gender differences in the sample, boy's and girl's means were compared on the primary study variables. Independent-sample *t*-tests were computed on children's interest in science, epistemological understanding, scientific reasoning, scientific self-efficacy, critical thinking, concept of science, perception of parent interest in science, and academic achievement. No significant differences emerged. There was a marginally significant difference between boys, $M = 4.21$ ($SD = 0.70$), and girls, $M = 4.47$ ($SD = 0.59$), on children's academic achievement, $t(78) = 1.82$, $p = .072$, $d = 0.41$. Because academic achievement was not one of this dissertation's main test variables, and only marginal differences were found, gender differences were not further examined in the analyses described below.

Intercorrelations of demographic and predictor variables with epistemological understanding and scientific reasoning were conducted. Several significant covariates emerged from the data. Ethnicity did not emerge as a significant covariate (epistemological understanding: $r = -.054$, $p = .64$; scientific reasoning: $r = .14$, $p = .23$). However, children's concept of science showed a small significant positive relation to epistemological understanding ($r = .27$, $p = .017$). Further covariates that emerged as significantly related to children's epistemological understanding and scientific reasoning were children's sense of scientific self-efficacy (epistemological understanding: $r = .29$, $p = .009$), their critical thinking skills (epistemological understanding: $r = .36$, $p = .001$), the number of topics in which the child were interested (epistemological understanding: *r* = -.30, *p* = .007), and their academic achievement (scientific reasoning: *r* = .34, *p* = .002). See Table 3 for the full list of intercorrelations.

Relation Between Children's Interest in Science, Age, and Children's Scientific Thinking

To address research question 1, which asked whether interest in science influences children's scientific thinking skills and how this relation differs with age, independent-samples *t*-tests and two ordinal regression models were computed. Children's scientific thinking was assessed by their epistemological understanding, which reflects their conceptual knowledge of evidence in relation to their own beliefs or theories, and their scientific reasoning, which reflects their skill at using evidence to find and defend conclusions. These variables were examined in relation to child age, as described in H1a, H1b, and H1c.

Hypothesis 1a: Children's scientific thinking at ages 9 and 12 years. To test for age differences in children's scientific thinking, epistemological understanding and scientific reasoning by 9-year-old and 12-year-old children were compared. An independent-samples *t*-test showed that children of both ages showed similar levels of epistemological understanding, $t(78) = -0.58$, $p = 0.56$, $d = 0.13$, but 12-year-old children displayed, on average, a higher level of scientific reasoning than 9-year-old children, $t(78) = 3.08$, $p = .003$, $d = 0.70$. Because age differences were found in children's scientific reasoning, age was included as a predictor variable in the regression model predicting children's scientific reasoning (H1c).

Hypothesis 1b: Relation of children's interest in science to epistemological understanding. Because children's epistemological understanding did not differ between age groups, age was collapsed for this analysis. Additionally, age was not tested as a moderator for epistemological understanding because moderators should be related to outcome variables to compute moderation analyses (Aguinis, 2004). Covariates that emerged as significantly related to children's epistemological understanding (i.e., children's critical thinking, concept of science, scientific self-efficacy, and number of interested science topics) were included in the regression model to account for these sources of variance.

Hypothesis 1b stated that children's interest in science will have a significant positive relation to their epistemological understanding. Hypothesis 1b was partially supported. The ordinal regression model predicted children's epistemological understanding from their interest in science, critical thinking skills, concept of science, scientific self-efficacy, and number of interested science topics ($\chi^2(5) = 25.37$, $p < .001$). Children's interest in science did not relate to the likelihood that children would be in a higher or lower level of epistemological understanding. An increase in one point in children's interest in science, as measured by the *Child's Interest in Science Questionnaire*, was related to a 50% decreased likelihood to be in a higher level of epistemological understanding (Wald, $\chi^2 = 1.61$, $p = 0.21$).

Significant relations were found for two intercorrelated covariates. Children's critical thinking and concept of science were the strongest covariates related to epistemological understanding. An increase of one point in children's critical thinking skills, as measured by the *Child Critical Thinking Survey*, was related to a 60% increased likelihood that children would be in a higher level of epistemological understanding (Wald, $\chi^2 = 5.71$, $p = 0.02$).

Because children's concept of science is an ordinal variable, the most commonly coded concept, *process*, was used as a comparison variable to analyze changes in children's epistemological understanding as a function of their concept of science. Children who were unable to define science (i.e., coded as *no response* on concept of science) were 96% more likely to have a lower level of epistemological understanding than children with a *process* concept of science (Wald, $\chi^2 = 3.92$, $p = .049$). Children who provided a vague or circular conception of science (i.e., coded as *identity* on concept of science) were 72% more likely to have a lower level of epistemological understanding (Wald, $\chi^2 = 3.92$, $p = .048$). Children who conceptualized science as science-related objects or activities (i.e., coded as *content* on concept of science) were likely to have similar levels of epistemological understanding as children with a *process* concept of science (Wald, $\chi^2 = 0.41$, $p = .52$). As children's conceptualization of science became more focused on scientific processes and activities, children's likelihood of understanding evidence as a component of scientific knowledge subsequently increased.

In addition to the significant covariates, two covariates also showed marginal relations to children's epistemological understanding. Children's scientific self-efficacy and the number of science topics in which children were interested were also marginally related to children's epistemological understanding. An increase in children's scientific self-efficacy was related to a 107% increased likelihood that children would be in a higher level of epistemological understanding (Wald, $\chi^2 = 3.03$, $p = .08$) and an increase in the amount of science topics children found interesting was related to a 8% increased likelihood that children would be in a higher level of epistemological understanding (Wald, $\chi^2 = 2.78$, $p = .10$). The model accounted for 28% of the variance in the epistemological understanding scores (Nagelkerke $R^2 = 0.28$). The 72% of unexplained variance suggests that children's epistemological understanding is a function of more than critical thinking, concept of science, and number of interested topics.

Children's critical thinking, scientific self-efficacy, and the amount of science topics in which children were interested were positively related to both children's interest in science and their epistemological understanding. Therefore, a post-hoc regression was computed in the interest of understanding how these covariates might mediate potential relations between children's interest in science and their epistemological understanding.

The mediation analysis showed that an increase in children's interest in science was significantly related to a 107% increased likelihood that children would be in a higher level of epistemological understanding (Wald, $\chi^2 = 4.47$, $p = .034$) before introducing the potential mediators described above and accounted for 6% of the variance in the model (Nagelkerke $R^2 = 0.06$). This finding suggests that children who were interested in science were more likely to express more evidence-based epistemological understanding. The second model added critical thinking as a potential mediator to the model. Children's interest in science was no longer related to children's epistemological understanding (Wald, $\chi^2 = 1.11$, $p = .29$), but children's critical thinking showed significant relations (Wald, $\chi^2 = 5.97$, $p = .02$). This model accounted for 13% of the variance in the model (Nagelkerke $R^2 = 0.13$). This finding suggests that the relation between children's interest in science and epistemological understanding was explained by the relation of children's interest in science to their critical thinking, which then related to children's epistemological understanding. Table 4 details the ordinal regression coefficients of the regression model for Hypothesis 1b with children's interest in science entered alone and with the covariates.

Hypothesis 1c: Relation of interest in science to scientific reasoning. Hypothesis 1c predicted that children's interest in science would relate positively to their scientific reasoning skills. The ordinal regression predicting children's scientific reasoning for their age and interest in science did not support Hypothesis 1c. As age differences were found for children's scientific reasoning, age was included as a predictor variable. The model also included children's critical thinking, self-efficacy, and academic achievement as covariates

The ordinal regression predicting children's level of scientific reasoning from their interest in science, academic achievement, critical thinking, and self-efficacy accounted for a significant amount of variance in children's scientific reasoning, $\chi^2(5) = 18.54$, $p = 0.005$. The model was a significant fit for the data, with children's age and children's academic achievement emerging as significant predictors of children's level of scientific reasoning. Twelve-year-old children were 69% more likely than 9-year-old children to show a more proficient level of scientific reasoning, and an increase in children's academic achievement of one point was related to a 250% increased likelihood that a child would show a more proficient level of scientific reasoning. Table 5 details the regression coefficients of this ordinal regression model. The model accounted for 21% of the variance in scientific reasoning (Nagelkerke $R^2 = 0.21$). The 79% of unexplained variance suggests that children's scientific reasoning skills are a function of more than children's age and academic achievement.

Because age differences were found for children's scientific reasoning, a moderation analysis was computed to examine whether children's age moderated the relation between children's interest in science and children's scientific reasoning skills. Adding the moderator variable did not increase the explanatory power of the model, $\Delta R^2 = 0.002$, $F(1, 75) = 0.20$, $p = .66$, and age did not moderate the relation between children's interest in science and their scientific reasoning, $\beta = -0.05$, $t(78) = -0.44$, $p = 0.66$. Therefore, children's interest in science related to their scientific reasoning similarly at age 9 and age 12.

Characteristics of Interest in Relation to Children's Scientific Thinking

To address research question 2 (what characteristics of interest relate to scientific thinking most strongly), an ordinal regression model was computed on children's epistemological understanding, with the four subscales of interest in science entered separately to examine the amount of variance explained by each one. To maintain power to detect effects and better investigate the unique variance among the four characteristics of interest, self-efficacy and topics of science interest were not included in this analysis. Self-efficacy and topics of science interest were chosen for exclusion due to their high amount of error and lower theoretical importance. To test H2a, an ordinal regression was computed with epistemological understanding. As no age group differences were found in relation to children's epistemological understanding, age groups were collapsed for the analysis testing Hypothesis 2a. An ordinal regression was not computed for children's scientific reasoning to test Hypothesis 2b due to children's interest in science not relating to children's scientific reasoning.

Hypothesis 2a: Characteristics of children's interest in relation to their scientific thinking. Hypothesis 2a stated that all four characteristics of interest in science will relate to children's epistemological understanding. An ordinal regression separating the characteristics of interest partially supported Hypothesis 2a. An increase in children's identification with science as an interest was related to a 5.95 times greater likelihood of being in a higher level of epistemological understanding (Wald, $\chi^2 = 8.66$, $p = .003$). Contrary to the hypothesis, children's enjoyment of science (Wald, $\chi^2 = 0.60$, $p = .52$), curiosity regarding science (Wald, $\chi^2 = 0.76$, $p = .38$), and valuing of science (Wald, $\chi^2 = 0.26$, $p = .61$) were not related an increased likelihood of being in a higher level of epistemological understanding. Table 6 details the regression coefficients of this ordinal regression model. The ordinal regression accounted for a significant portion of the variance, $\chi^2(4) = 29.54$, $p < 0.001$. The model accounted for 32% of the variance in epistemological understanding (Nagelkerke $R^2 = 0.32$), similar to the model computed for H1b.

Parents' Interest in Science in Relation to Children's Interest in Science

To address research question 3 (whether children's interest in science relates to their parent's interest in science), a simple regression was computed with children's interest in science as the outcome variable and parents' interest in science as the predictor variable. As no age differences were found for children's interest in science, $t(78) = 0.10$, $p = 0.92$, age groups were collapsed for analyses to test Hypotheses 3a and 3b. Potential covariates of parental science self-efficacy and enjoyment were not included in the regression models because children's interest in science did not significantly correlate with either parents' science self-efficacy ($r = -077$, $p = .50$), or parents' enjoyment of science ($r = .092$, $p = .42$). Because only one father was present in the sample, father scores were dropped for analyses testing Hypotheses 3a and 3b, therefore the sample for these analyses was $n = 79$. However, as children reported on their perception of both their father's and mother's interest in science, children's perception of father's interest in science was maintained for the analyses.

Hypothesis 3a: Children's interest in science will relate to parent's interest in science. Hypothesis 3a predicted that children's interest in science would have a significant positive relation to their parent's interest in science. Hypothesis 3a was not supported. Mother's self-reported interest in science did not predict children's interest in science, $\beta = 0.07$, $t\ (77) = 0.66$ $p = 0.51$. The model did not explain a meaningful amount of variance in children's interest in science, $R^2 = 0.09$, $F(1, 76) = 0.43$, $p = 0.51$. This finding suggests that children's interest in science is not a function of their mother's self-reported interest in science.

Hypothesis 3b: children's perception of parent's interest in science will moderate the relation between parents' interest in science and children's interest in science. Hypothesis 3b predicted that the relation between parent and child interest in science will be moderated by children's perception of their parents' interest in science.

Hypothesis 3b was not supported. A moderator analysis did not increase the explanatory power of the model, $\Delta R^2 = 0.007$, $F(1,76) = 0.66$, $p = .42$, and the children's perception that parents were interested in science did not moderate the relation between children's interest in science and mother's interest in science, $\beta = -0.09$, $t(77) = -0.81$, $p = 0.42$.

Since Hypothesis 3a was not supported, an exploratory regression analysis was computed adding children's perception of parents as interested in science to the model to explore the main effects of children's perception of their parents' interest in science. The second model revealed that children's perception of their parents' interest in science related to children's interest in science, $\beta = 0.45$, $t(7) = 4.31$ $p < .001$, and strengthened the relation of children's interest in science to mother's self-reported interest in science so that the relation now had a trending significance, $\beta = 0.16$, $t(77) = 1.50$, $p = 0.14$. This finding suggests a suppression effect between parent's interest in science and children's perception of parents as interested in science and called for a post-hoc regression analysis. This model explained 20% of the variance in children's interest in science, $R^2 = 0.20$, $R^2_{adjusted} = 0.17$, $F(2, 76) = 9.59$, $p < .001$.

***Hypothesis 3b post-hoc analysis*.** Because mother's interest in science increased in predictiveness with the addition of children's perception of parent interest, there is evidence of a suppression effect. Because mothers can interact with children in different ways during science activities and talking about science-related topics (Crowley et al., 2001) and fathers' self-reported interest in science were not included in the initial analyses, the suppression effect was explored by separating children's perceptions of their mother's and father's interest in science. In the post-hoc model, children's perception of their mother as interested in science significantly related to children's interest in science, β = 0.41, t(77) = 3.62 p = .001, while perception of their father as interested in science did not, $\beta = 0.14$, $t(77) = 1.17$ $p = .24$. Mother's self-reported interest in science continued to have no relation and did not have the same suppression effect as it did in the prior model, $\beta = 0.11$, $t(77) = 1.01$, $p = 0.31$. This model explained 25% of the variance in children's interest in science, $R^2 = 0.25$, $R^2_{adjusted} = 0.22$, $F(3, 75) = 8.20$, $p < .001$, suggesting that children's interest in science is a function of their perception of mothers as interested in science and not their fathers as interested in science, nor their mothers' self-reported interest in science. Table 7 shows the initial regression coefficients and the post-hoc regression model coefficients.

Summary of Findings

This dissertation sought to extend our understanding of the relation between children's interest in science and their scientific thinking skills, and how these relations differed at ages 9 and 12 years, while accounting for potentially related social factors (e.g., parents' interest in science) and individual factors (e.g., self-efficacy and critical thinking). The tests for Hypothesis 1a was based on the theoretical assertion that scientific thinking tasks require complex cognitive processes that are better developed at age 12. The results from the tests for Hypothesis 1a partially support this theoretical assertion. The test for Hypothesis 1a showed age differences in children's scientific reasoning skills but not their epistemological understanding. However, age did not moderate the relation between children's interest in science and either their epistemological understanding or their scientific reasoning. Hypotheses 1b and 1c are based on the theoretical assertion that children will explore and discuss scientific topics as they become more interested in science, which will provide opportunities to develop their scientific thinking. The results of the tests for Hypotheses 1b and 1c partially support the theoretical assertion that children's interest in science is an important factor for epistemological understanding. However, the results refute the assertion that children's interest in science is an important factor for scientific reasoning. The evidence suggests that children's interest in science and concept of science significantly related to children's epistemological understanding, although children's interest in science is mediated by children's critical thinking in that children who were more interested in science reported more critical thinking that related to their epistemological understanding. In contrast, children's scientific reasoning is a function of children's age and academic achievement.

The second aim of this dissertation is to investigate the relation of children's interest in science and their scientific thinking in greater detail by examining the four characteristics of interest (i.e., enjoyment, curiosity, value, and identification). Tests of Hypotheses 2a and 2b were based on the theoretical assertion that, while all characteristics of interest are important for children's scientific thinking skills, identification and curiosity will show the strongest relation. This dissertation argues this position because identification with an interest in science and curiosity regarding science have been linked to greater amounts of explanation and information seeking (Azevedo, 2015; Legare, 2014) and are therefore more foundational to core scientific thinking skills. The test for Hypothesis 2a partially supports this assertion, with identification with science relating to greater epistemological understanding. The test for Hypothesis 2b did not support this assertion, with children's overall interest in science not relating to children's scientific reasoning.

The third aim of the study was to gain a better understanding of the other factors that might affect the relationship between children's interest in science and their scientific thinking. The tests for Hypotheses 3a and 3b were based on the theoretical assertion that children's overall interest in science is influenced by their social relationships, primarily those with their parents. The results from the test for Hypothesis 3a did not support this theoretical assertion. Children's interest in science did not relate to mother's interest in science nor was it moderated by children's perception that their parents were interested in science. The results from the post-hoc analyses partially supported this theoretical assertion. The test showed that children's interest in science was related to their perception that their mothers were interested in science but not related to their mother's actual self-reported interest in science.

Several important covariates emerged from the exploratory analyses. While neither gender nor ethnicity influenced children's scientific thinking skills, individual differences in children's general critical thinking, self-efficacy, conceptualization of science, and the breadth of science topics in which children were interested emerged as significantly intercorrelated with epistemological understanding. These tests showed that children's understanding of knowledge related to not just how they thought about science, but related to how they thought about other domains of information (i.e., media) and how they conceptualized science and their relation to science (e.g., that science is a process and that they are capable of successfully understanding scientific information).

Discussion

The current dissertation aimed to fill in gaps in the literature on children's scientific thinking and interest in science by investigating how interest in science relates to the development and utilization of children's scientific thinking skills at ages 9 and 12 years. Children defined their concept of science and reported their interest in science and general epistemological understanding before solving science-related problems. It was hypothesized that children's interest in science would have a significant positive relation to their scientific thinking skills because scientific thinking requires intentional practice and exploration of scientific topics (Kuhn, 2011; Zimmerman, 2007). Furthermore, because children over the age of 10 show more defined interest in science (Renninger et al., 2015) and greater scientific thinking skills (Klaczynski, 2011), it was hypothesized that this relation would be stronger for children age 12 than children age 9.

The dissertation had four main findings. One, though age did not moderate any of the relations described below, age differences did emerge in children's scientific reasoning. Two, children's interest in science, mediated by their critical thinking, and their concept of science related to greater amounts of evidence-based epistemological understanding but did not relate to children's scientific reasoning. Three, children's identification with science was the only characteristic of interest that related to children's epistemological understanding. Four, mother's interest in science also showed no relation to children's interest in science, but children's perception that their mothers were interested in science related to children's interest in science. Mothers are discussed in relation to the findings because the one father who participated in the study was dropped from the analyses and children's perception of mothers was the main predictor of children's interest in science. These four main findings and their implications for the development of children's scientific thinking will be discussed below.

Age Differences in Children's Scientific Thinking

The first main finding responded to research question 1 (How does the relation between interest in science and scientific thinking differ with age?). While epistemological understanding showed no age differences, results showed that 12-year-old children were more likely to perform better in the scientific reasoning tasks than 9-year-old children. The relation between age and scientific reasoning suggests that children's reasoning skills may benefit substantially from changes in the ability to monitor their acquisition of new information and apply it to their decisions (e.g., deciding what variable makes water clean; Klaczynski, 2006).

Age. One explanation for the observed age differences is that 12-year-old children possess a more developed capacity to reflect upon new information they have acquired in order to find solutions for the reasoning tasks with the evidence presented to them. Using evidence to reason about outcomes, especially counterintuitive outcomes, requires the ability to monitor one's own learned information proficiently enough to evaluate one's prior theories that does not typically develop until adolescence (Klaczynski, 2006). Prior research shows adolescents who reflect upon new information more thoroughly show generally greater scientific reasoning skills (Amsel et al., 2008). Twelve-year-old children performed significantly better on the scientific reasoning tasks than 9-year-old children. Twenty percent of 12-year-old children successfully solved both problems while only 7.5% of 9-year-olds did. Conversely, 13.75% of 12-year-olds were unsuccessful on both problems while 23.75% of 9-year-olds were. These findings may indicate that 12-year-old children are better able to mentally monitor and manipulate new information to scientifically reason than 9-year-old children (Feist, 2008; Bullock et al., 2009). This ability to monitor the information one has learned and reflect upon that information to revise one's prior theories, termed metamonitoring, does not usually fully develop before adolescence (Klaczynski, 2006). Therefore, age-related developments in children's ability to mentally reflect upon new information and integrate conflicting information may aid in the development of their scientific reasoning skills.

The metamonitoring explanation gains further support by investigating the qualitative differences between 9 and 12-year-old's responses. Low-scoring responses on the scientific reasoning task largely reflect thinking that favors prior theories children hold over evidence-based reasoning when explaining their conclusions, termed theory-based and evidence-based thinking respectively (Kuhn, Amsel, & O'Loughlin, 1988). Nine-year-olds predominantly responded with this theory-based thinking while trying to explain their solutions to the reasoning tasks, while 12-year-olds expressed far greater utilization of evidence. Previous research has shown that prior beliefs can cause people to distort or disregard new evidence to support their prior theories (Amsel et al., 2008; Zimmerman & Croker, 2014) and these prior beliefs remain despite acquiring contradictory information (Shtulman & Valcarcel, 2012). Thus, as 12-year-olds develop their capability to monitor their own thinking in relation to new information, they may be better equipped to recognize new information as potentially important evidence and favor that over their prior theories when reasoning about some phenomenon (e.g., clean water or livable planets). Furthermore, the finding that children's interest in science showed no relation to their scientific reasoning skills suggests that the development of metamonitoring abilities is not influenced by children's interests.

Alternatively, as academic achievement also related to scientific reasoning, 12-year-old children may have learned reasoning strategies that 9-year-old children have not yet learned. Twelve-year-old children are predominantly in grades 6-7, in which science instruction places a greater emphasis on experimentation processes and evidence coordination (National Research Council, 2013). Scientific reasoning requires the coordination of multiple pieces of evidence to produce an answer to some question or provide an explanation for some observation. This coordination of evidence requires children to reflect upon and monitor entirely mental representations of evidence or facts to revise one's theories (Kuhn & Franklin, 2006). The relation of academic achievement to scientific reasoning supports this interpretation. Academic achievement is related to children's metamonitoring and scientific reasoning at age 12 (Feist, 2008). Therefore, the more complex reasoning task used in this dissertation may have required greater amounts of mental reflection and coordination that are strengthened in the science lessons in which 12-year-olds have participated but may have been beyond the capabilities of 9-year-old children who have not had these lessons yet.

No age differences were found for children's epistemological understanding. Multiplist and evaluativist epistemologies can develop as early as 5 – 6 years old (Moshman, 2014). Children's epistemological understanding develops along a trajectory of absolutist to evaluativist as a function of personal experience, such as science instruction and experience with argumentation (Kuhn, 2011). These experiences usually happen in social contexts in which children can engage in activities where knowledge is constructed and evaluated (Sandoval, 2018). For instance, children who discuss the creation of objects, such as how the pyramids were constructed, can develop their concepts of knowledge being due to some evidentiary fact (Valle, 2009). Children can also develop these concepts through solitary practices such as reading and self-directed speech (Vygotsky, 1978; Zavala & Kuhn, 2017). Thus, children in this dissertation may have achieved a general epistemological understanding by age 9, and their personal experience with science topics may have been a factor relating to its further development. The results of this dissertation support this interpretation by showing that the lack of age differences was not due to a ceiling effect. Twenty percent of 9-year-old children and 23.75% of 12-year-old children reported an evaluativist epistemological understanding in at least one domain, as defined by a score of five or higher on the *Jaime & Terry* Questionnaire, with 76.25-80% of children responding with multiplist or absolutist epistemological understandings. Therefore, it is not the case that children's epistemological understanding is fully developed by age 9, but suggests that individual experiences might underlie the development from a multiplist to an evaluativist understanding. This dissertation suggests that the cognitive abilities required to develop a fully-evaluativist epistemological understanding are present at age 9, and that an interest in science may be an important, albeit indirect, factor in developing children's epistemological understanding further.

These results signify that both 9-year-old and 12-year-old children are able to understand how evidence supports knowledge across several domains (e.g., social science truth, physical science truth), but 12-year-old children are better able to reflect upon that evidence to revise or reinforce their theories (e.g., whether clean water is related to greater amounts of rain or higher temperatures). Sophisticated epistemological understanding requires children to understand that knowledge is derived from some sort of evidence, and the strength or persuasiveness of that knowledge is informed by the quality of that evidence. Scientific reasoning requires that same understanding of evidence, but also requires that children reflect upon that evidence to evaluate some sort of outcome or decision. Thus, 12-year-old children may be better able to cognitively manipulate variables to reason about their own hypotheses than 9-year-old children (Feist, 2008).

For instance, 12-year-olds may learn reasoning skills during science or current events lessons that help children apply their epistemological understanding to reasoning problems in multiple scientific and non-scientific situations (Feinstein et al., 2013). These findings provide a potential developmental trajectory for scientific thinking. Epistemological understanding of evidence and knowledge may precede scientific reasoning that utilizes this understanding to reason about and coordinate evidence to revise or reinforce one's prior theories.

Gender Differences in Children's Scientific Thinking and Interest in Science

Unexpectedly, children's gender did not relate to children's interest in science, epistemological understanding, or scientific reasoning. One explanation for this may be that children of both genders had generally high academic achievement, with girls having marginally higher achievement than boys. Therefore, girls' higher academic achievement may have buffered any potentially negative effects of scientific thinking arising from social or stereotypical beliefs (Archer et al., 2010; Feist, 2008; Rhodes et al., in press). Another explanation is that the children in this sample were not yet old enough to have noticeable gender differences in their interests in science. Gender differences become largest in early adolescence, around the age of 13-14 years (Lei et al., 2019). However, this explanation is less likely than the first, as prior research into children's views of science shows these gender differences emerging by age 10 (Archer et al., 2010). Lastly, girls may have had higher interest in science due to selection bias in the sample used for this study. As the study was voluntary, perhaps girls who were not interested in science were less willing to be in the study. However, the mean for girls' interest in science was comparable to boys and was centered on the average point in the children's interest in science scale. Therefore, this explanation is similarly less likely than the first.

Relation Between Children's Interest and Scientific Thinking

The second main finding also responds to the first research question (does children's interest in science relate to their scientific thinking?). Children's interest in science and concept of science were related to children's epistemological understanding, with interest in science mediated by children's critical thinking skills. No relation between interest and science and scientific reasoning was found.

Relation between children's interest in science and their epistemological understanding. The results showed that children's interest in science related to their epistemological understanding, and that this relation was mediated by children's concept of science and their critical thinking skills. These findings partially support Hypothesis 1b which asserts that children's interest in science will relate to the epistemological understanding component of scientific thinking. Children's interest in science may relate to their epistemological understanding because scientific inquiry involves uncovering answers to research questions (Bullock et al. 2009).

According to a situative view of epistemic cognition, one's epistemological understanding is socially constructed from communal situations in which knowledge is explored and verified, such as resolving disagreements with other people and discussing contradicting information (Sandoval, 2018). Discussions and argumentation have been linked to development of children's epistemic cognition by previous research (Valle, 2009; Zavala & Kuhn, 2017) and children who are interested in science in general spend more time engaged with scientific topics and discuss scientific topics at greater length (Renninger & Hidi, 2016). Therefore, as children become interested in science, they may be more likely to encounter scientific disagreements that help develop their epistemological understanding. This interpretation is contradicted by findings in this dissertation that show children's overall time spent in scientific activities outside of school did not relate to either children's interest in science or epistemological understanding. As such, children's epistemological understanding and interest cannot be said to be a function of merely more time spent involved with scientific topics. The post-hoc analysis provided insights into a potential pathway in which these two constructs relate.

The relation between children's interest in science and epistemological understanding was mediated by children's critical thinking. When children reported higher interest in science, they similarly engaged in greater critical thinking, and subsequently utilized more evaluativist epistemological understanding (i.e., that knowledge is derived and supported by evidence). Therefore, these findings suggest that children's interest in science relates to their epistemological understanding by potentially influencing how they consider information in non-scientific situations (e.g., while consuming media). Critical thinking as a mediator between children's interest in science and their epistemological understanding will now be discussed in greater detail.

Critical thinking as mediator between children's interest in science and epistemological understanding. The ordinal regression showed that children's critical thinking mediated the relation between children's interest in science and their epistemological understanding. The relation suggests that children who reported more interest in science also reported looking at underlying evidence or approaching claims with more skepticism even outside of scientific topics, which then relates to children's expressing more evidence-based epistemological understanding. One explanation for this mediation may be that interest in science motivates children to consider the underlying information of contradicting claims, and thereby practice their critical thinking skills that can then be extended beyond science domains. Interest relates to an increased amount of solution-seeking and increased focus when engaging with interested topics (Hidi & Renninger, 2010). Additionally, children's prior content knowledge can aid in their critical evaluations of new information (Tsai, Chen, Chang, & Chang, 2013). Consequently, children's focused engagement with science topics related to interest in science may then help develop children's general critical thinking skills that in turn relates to children developing a more evaluativist epistemological understanding.

The critical thinking measure focusing on non-science topics also suggests that this engagement may lead them to think about other topics more critically. Prior experience with evidentiary thinking increased the likelihood that someone will employ evidentiary thinking in different contexts (Koslowski, Marasia, Chelenza, & Dublin, 2008). Therefore, if children's interest in science aids them in understanding the role of evidence, they may be more likely to employ a similar thinking in non-science contexts. Children's interest in science may then relate to children's self-reported critical thinking in non-scientific topics, which can then be applied to different contexts. Thus, this relation suggests that children's interest in science relates to their epistemological understanding by influencing how children think about claims more generally. Similarly, if children's interest in science helps them apply evidence to non-scientific claims, children may develop their understanding of evidence's role in supporting or refuting knowledge in a more domain-general way.

These interpretations should be generalized with some degree of caution, as the measure used for children's critical thinking was self-report and only focused on one different situation (i.e., media consumption). This dissertation cannot, therefore, speak to how proficiently children think critically about media or other topics. However, these findings are important as they suggest children's increased interest in science relates to the way they view messages even in non-science topics which then aids in their understanding of how knowledge is derived. Furthermore, these findings suggest that an interest in science can help children become more aware consumers of media, an important issue facing 21st century children (Wineburg et al., 2016).

Relation between children's concept of science and their epistemological understanding. Children's concept of science, as shown in the ordinal regression and post-hoc mediation analysis, emerged as significantly related to children's epistemological understanding. Thus, children's conceptualization of evidence as a key component of science might assist in developing a more general understanding of the relation between evidence and knowledge. These findings support prior research that show children's concept of science affects their scientific problem solving. Children who have developed a greater understanding of science as a process to test hypotheses at age 11 were better able to understand evidence as a component of scientific reasoning at age 12, 16, and into adulthood (Bullock et al., 2009). This relation has also been demonstrated at earlier ages. Children age 8 to 10 who demonstrated more developed conceptual understanding of how information is constructed from scientific information also showed greater epistemological understanding and conceptual understanding of science as a process of hypothesis testing (Osterhaus et al., 2017). Furthermore, epistemological understanding of scientific topics concerns itself with justifying conclusions about children's observations, and development requires children to understand that science information is formed from people using evidence to justify scientific claims (Moshman, 2014). These findings support the situative view of epistemological understanding as socially constructed, and point to a concept of science potentially relating to that construction. Children, through their interactions with others around them during which they justify their theories about the world, develop their concept of science as defined by a search for knowledge, and knowledge itself as derived from evidentiary facts. Thus, the relationship between children's concept of science and their epistemological understanding suggests that children who conceptualize science more in terms of experimentation and justification may also better understand the role of evidence as a component of scientific knowledge.

Individual differences related to children's epistemological understanding. In addition to children's interest in science, critical thinking, and concept of science, children's epistemological understanding was marginally related to children's scientific self-efficacy and the breadth of their scientific interests. Children's self-efficacy may have related to children's epistemological understanding by influencing children's willingness to engage with the scientific information or that children with a better understanding of evidence feel more confident in doing scientific tasks. Additionally, the breadth of scientific interests negatively related to children's epistemological understanding possibly due to the level of engagement related to a singular interest as opposed to a more diffuse interest. Though marginal, these findings have implications for the development of children's epistemological understanding that bear some further exploration.

Self-efficacy. Children's epistemological understanding was marginally related to children's self-efficacy. This finding suggests that children's understanding of knowledge relates to their perceived ability to do scientific tasks. This may be due to children who are interested in science are more confident in their ability to succeed in science-related activities and therefore are more likely to seek out more demanding science-related tasks that help develop their epistemological understanding. This finding reflects prior research showing that children with an interest and feeling of self-efficacy regarding mathematics had higher achievement in mathematics during adolescence (Kim et al., 2015). Children who feel more able to accomplish scientific tasks may persist in difficult scientific tasks or put in greater effort into scientific tasks. These more demanding tasks may have provided experience with explanatory evidence that relates to developing epistemological understanding (Kuhn, 2011). However, because this relation was only marginal, with a high standard error (as can be seen in Table 4) and relatively low measure reliability, this dissertation takes caution when interpreting these findings.

Breadth of science interest. The breadth of children's interest in science, as measured by the number of topics in which children reported an interest, was also marginally related to children's epistemological understanding. Interestingly, the number of topics in which children were interested was negatively related to scientific reasoning, suggesting that children with a narrower range of scientific interests may share some small relation to their epistemological understanding. One interpretation of this finding is that children who are interested in many different topics of science have not deeply engaged with any one topic and, therefore, may not have explored the topic to the extent necessary to sufficiently develop scientific reasoning skills in it. Children may also have reported liking topics in which they had only a passing interest, and the measure did not capture children's science-related interest as accurately as the *Children's Interest in Science Questionnaire* that measured the level of their interest in science.

This relation suggests that children who explore more topics related to science may develop a slightly better understanding of knowledge and evidence than those who are only deeply interested in a singular topic. However, this find was only marginal and the measure only assessed a very general interest in on specific topics. Therefore, this dissertation takes caution in interpreting these results.

Relation between children's interest in science and their scientific reasoning. Hypothesis 1c stated that children's interest in science will relate to children's scientific reasoning skills. The hypothesis was not supported. The ordinal regression to test Hypothesis 1c showed that scientific reasoning was only significantly related to children's age and children's academic achievement. These findings suggest that children's interest in scientific topics do not relate to children's capabilities at coordinating evidence to find answers to scientific questions.

This lack of relation may be due to prior information in science-related topics that children might acquire while exploring their topics of interest. Children with high interests in particular topics, such as wild animals, typically have greater content knowledge in those topics (Renninger et al., 2002). Therefore, children who are interested in science may generally have greater content knowledge about scientific topics. This prior knowledge may then bias their reasoning by having them rely more on these prior theories than the available evidence. Prior knowledge has been shown to influence scientific reasoning (Koslowski et al., 2008). However, if this explanation were true, a negative relation between children's interest and scientific reasoning may be expected. As no such relation was found, the explanation that children's scientific reasoning skills rely more on their metamonitoring abilities than individual interests better fit the results. Individual differences in academic achievement was found to be related to children's scientific reasoning, as will be discussed below.

Individual differences related to children's scientific reasoning. While children's interest in science did not relate to children's scientific reasoning, children's academic achievement, in addition to their age as discussed above, was related to children's scientific reasoning. This finding supports prior research that shows scientific reasoning showing positive relations to children's academic achievement at age 10 (Lazonder & Wiskerke-Drost, 2015), in adolescence (Kim et al., 2015), and into adulthood (Zimmerman & Croker, 2014). Furthermore, the breadth of children's interest in science, as measured by the number of scientific topics in which they reported an interest, showed a marginal relation to children's scientific reasoning.

Academic achievement. Academic achievement was significantly related to children's scientific reasoning. One explanation for academic achievement, but not interest in science, being related to scientific reasoning is that scientific reasoning requires specific and direct strategies (Kuhn, 2011). Sophisticated scientific reasoning requires strategies such as altering one variable while maintaining consistency of other variables (Bullock et al., 2009). Children who engage in more science-focused education as they enter middle school at ages 11-12 showed greater scientific reasoning skills, such as utilization of the control-of-variables (CVS) and ability to discover relations between variables (Bullock et al., 2009; Dierks et al., 2016).

Thus, a general interest in science, while promoting exploration in areas related to science, does not appear to provide the level of structured training required to develop these complex reasoning skills. Children's scientific reasoning skills appear determined substantially more from their academic achievement than a high or low interest in science. Alternatively, as children's significant age differences were found in children's scientific reasoning (discussed in greater detail above), children's reasoning skills may relate to lessons taught in the junior high grades (grade 6-7) from which 12-year-olds will benefit, but not 9-year-olds.

Breadth of science interests. Interestingly, the number of topics in which children expressed an interest showed a marginal negative relation to children's scientific reasoning. Therefore, children who are interested in more science-related topics appear to perform lower on scientific reasoning. Research into how scientific reasoning develops through explanations of unexpected results may help interpret these findings.

People develop reasoning skills, in part, by explaining unexpected occurrences (Legare, 2012). For instance, if a child predicts that volcanic activity will cause planets to be livable or unlivable and finds that not to be the case, their theory no longer adequately explains the world around them. In order to resolve this disequilibrium between the child's theory and their observations, they must then figure out why such an observation occurred to adjust their theory (Schaffer, 2006). In explaining the unexpected outcomes and revising their theories about the world, children develop their reasoning skills (Klaczynski, 2011). Children who are interested in many topics may have a more surface-level of knowledge in each area and may not encounter unexpected results as often. Alternatively, children with a generally positive view of "science" may have reported being interested in topics in which they only had a passing or superficial interest, but their responses did not represent actual time engaging or exploring those topics. Next, I will discuss how the characteristics of interest in science relate to children's epistemological understanding more thoroughly.

Relation Between Characteristics of Children's Interest in Science and Scientific Thinking

The third main finding of this dissertation corresponded to tests of Hypothesis 2a, that the four characteristics of science – enjoyment, curiosity, value, and identification with science – will positively relate to scientific thinking. Hypothesis 2a was not supported. Only children's identification with science (e.g., "*I am a science-minded person*") showed a relation to epistemological understanding. Children's overall interest in science as measured by their responses to the *Child Interest in Science Questionnaire* was not related to their scientific reasoning, therefore no further analyses were conducted. These results can be explained by the different ways that these characteristics of interest may encourage children to engage with science-related topics (Renninger & Hidi, 2016). Enjoyment and valuing of science may not have been related to epistemological understanding, perhaps because one can enjoy science content (e.g., rocket ships, animals, etc.) or believe that science is valuable without investing time to understand the connections between evidence and knowledge that underlie that content (Ainley & Ainley 2011). Additionally, curiosity may not relate to epistemological understanding because curiosity can characterize earlier phases of interest (Hidi & Renninger, 2006) and trigger new interest in science (Renninger & Bachrach, 2015). Thus, curiosity may appear during lower phases of interest that do not afford children to develop an understanding of evidence and knowledge. These characteristics are described in greater detail below in the discussion of Hypothesis 2b.

Hypothesis 2b predicted that curiosity and identification with science will be more related than enjoyment and valuing science. Hypothesis 2b was partially supported. Results of the ordinal regression separating the four characteristics of interest in science showed that children who identified as interested in science, as assessed by their responses to the identification items in the *Child's Interest in Science Survey*, were significantly and positively related to children's epistemological understanding. No characteristic of interest emerged as significantly related to children's scientific reasoning.

Enjoyment of science. Contrary to Hypothesis 2a and 2b, children's enjoyment of science did not significantly relate to children's epistemological understanding or scientific reasoning. These results suggest that children's scientific thinking is not related to how much children enjoy science. Children may enjoy many different scientific topics, such as wild animals or creating chemical reactions (e.g., baking soda causing vinegar to foam), that do not inform children about hypothesis testing (Azevedo, 2015). As a result, children might enjoy participating in these science-related topics, but not attend to the information about coordinating theory and evidence to develop either their epistemological understanding or scientific reasoning. The interpretation that enjoyment may lead children to enjoy science-related topics, but not necessarily engage with the scientific process of experimentation, is supported by children's interest in science showing no relation to children's conceptualization of science as a process of hypothesis testing as 43.75% of children defined science either self-referentially or as some science-related object (e.g., science involves rocks). These findings suggest that children who enjoy science may not understand experimentation as an important component of the process, and therefore may not attend to that information.

Alternatively, children's positive affect regarding a scientific topic (i.e., their enjoyment) can often occur at the beginning phases of interest according to Renninger and Hidi's (2006) four-phase model of interest. While enjoyment can motivate future engagement (Ainley & Ainley, 2011), it may be indicative of earlier phases of interest that have not yet led children to experiment with scientific information. Therefore, children who have a relatively new or surface-level of interest in science may report a high level of enjoyment but have not yet engaged with scientific thinking processes (e.g., experimentation).

Curiosity regarding science. Contrary to Hypotheses 2a and 2b, children's general self-reported curiosity regarding science showed no relation to either children's epistemological understanding or their scientific reasoning. This finding contradicts what might be expected in prior research that shows even self-directed science activities and interactions in which children explore science-topics with others can relate to increases in children's epistemological understanding (Valle, 2009) or scientific reasoning (Crowley et al., 2001). It does, however, support findings that scientific thinking requires very explicit, structured directions (Lazonder & Wiskerke-Drost, 2015). Children's general curiosity about scientific topics (e.g., seeking out information about science in their spare time) appears unrelated to instances in which children explain unexpected outcomes or engage with disagreements related to developing epistemological understanding (Kuhn & et al., 2017) or scientific reasoning (Legare, 2014).

One explanation for why the findings contradict prior findings that curiosity behaviors relate to epistemological understanding (Valle, 2009) may be that reported curiosity does not reflect observed curiosity. The current dissertation measured children's self-reported predisposition to seek out and engage with science-related topics, mirroring Renninger and Hidi's (2016) conceptualization of curiosity (e.g., "*I would spend my spare time learning science*"). It could be that a curiosity that related more directly to behaviors, such as pursuing information in the face of inconsistent or contradictory findings, may relate to one's epistemological understanding or scientific reasoning. This may better capture the curiosity-driven behaviors seen in previous research demonstrating connecting curiosity to children's propensity to explore a problem space and uncover answers to science-related questions (Legare, 2014; Valle, 2009).

Valuing science. The tests for Hypothesis 2a and 2b showed that children's valuing of science did not relate to children's scientific thinking. These results suggest that placing an importance on science does not influence one's understanding of knowledge and coordination between theory and evidence. One explanation may be that valuing science predisposes people towards accepting scientific information, which might bias their processing or reasoning about such topics. Prior biases can cause people to alter or reject new evidence that might contradict those biases (Klaczynzki, 2006). Furthermore, people may be more likely to rely on prior beliefs with commonly encountered scientific topics, such as water (Dolnicar & Hurlimann, 2011; Shtulman, 2013). If children value science, they may rely more on prior information learned from seemingly scientific sources when reasoning or thinking about evidence. However, children's value of science did not have a negative relation with children's epistemological understanding or scientific reasoning. Therefore, these results suggest the value children place on science neither impedes nor assists in the development of their scientific thinking skills.

Identification with science. Children's identification with science was the only characteristic of interest in science to show a significant relation to children's scientific thinking. Children who identified with science as an interest were significantly more likely to express greater amounts of evaluativist thinking in their epistemological understanding, which means that children were more likely to conceive of knowledge as derived from evidence as they reported a greater identification with science as interesting.

One explanation for identification being the only characteristic of interest related to epistemological understanding could be due to identity exemplifying the most involved phases of interest. According to the four-phase model of interest, children include being interested in science into their self-concept when they form long-lasting deep interests in topics (Renninger & Hidi, 2015). Such identity-related interests have been linked to persistent engagement with topics of interest and a greater likelihood of continuing to engage with that topic into adulthood (Azevedo, 2015). These findings are in-line with prior research that shows children who identify as interested in science are more likely to engage in difficult or complex science topics and explore more science-related topics (Archer et al., 2012; Rhodes et al., in press). Therefore, children who identify with science may be those who are the most likely to have engaged with science activities that require the necessary explanation and inquiry to develop their epistemological understanding.

Alternatively, as children who identify with science as an interest may explore science topics in more fields, they may be more prone to apply their scientific epistemological understanding to more domains than those in a lower phase of interest. The second interpretation is supported by the finding that number of topics in which children were interested also showed a marginal positive relation to children's epistemological understanding.

No such relation was found between the characteristics of interest and children's scientific reasoning. This may be because children's scientific reasoning skills require particular strategies, such as the control of variables strategy (Bullock et al., 2009). This strategy often requires explicit directions that may not be encountered through interest-directed exploration of science-related topics, (Valle, 2009; Kuhn et al., 2017). As age and academic achievement were the significant predictors of children's scientific reasoning skills, children's scientific reasoning may be associated with age-related developments in children's reasoning abilities or influenced by the social contexts in which children develop. To discuss social influences on children's interest in science, this dissertation now examines the relation between children's interest in science and their mother's interest in science.

Relation Between Parents' Interest in Science and Children's Interest in Science

The final main finding related to the third research question pertained to whether children's interest in science was related to their parent's interest in science and whether this relationship was moderated by children's perception of their parent's interest. Hypothesis 3a, that children's interest in science would be related to their parent's interest in science was not supported. Parents' self-reported interest in science showed no relation to children's interest in science. Hypothesis 3b, that children's perception that their parents were interested in science would moderate this relation, was not supported. However, while children's perception of parent interest did not moderate any relation between mother and child interest in science, children's perception of their mothers, but not their fathers, as interested in science positively related to children's level of interest in science. Since only one father was present in the study and subsequently not used in the analyses for this research question, we cannot generalize these results to father's reported interest in science. Therefore, this relation will only be discussed regarding mothers and children.

The results underscore the importance of children's perceptions of a parent's interest in science. Children's perception that their mothers find science interesting and valuable may be more important to developing children's interest in science than their mother's actual self-reported interest in the topic. One explanation is that parent-child interactions provide rich contexts for engendering interest in science and exploration of scientific topics. Parents who interact with their 8-year-old children during scientific tasks in science museums had children who expressed greater exploration during those tasks (Crowley et al., 2001). Mothers who talked with their children age 8 to 11 about scientific topics (e.g., evolution) had children with greater content knowledge about scientific topics (Valle, 2009). As a result, if mothers interact with their children in positive ways on science-related topics (e.g., science fairs, science museums), children may internalize science as an interesting and worthwhile topic to explore further.

Mothers may also convey a belief that science is interesting to their children outside of direct interactions through their behaviors during everyday practices. Prior research has shown that parents convey messages about their beliefs (e.g., science is valuable) to their children indirectly through their practices, such as reading science magazine or discussing new scientific discoveries, and displays of affect, such as showing excitement at hearing about science news (Goodnow, 1992). Children may also receive messages about science as interesting from observing their parents in everyday situations. Social experience influences the topics children think about and their beliefs on those topics (Gauvain & Perez, 2015). Thus, children may become more interested in science if they observe their mothers expressing an interest in science or interact with science in a positive way, even if the children are not actively interacting with their mother. Furthermore, beliefs about valuable practices and ways of knowing are socially constructed through interactions with others and observing the actions of others (Sandoval, 2018; Super & Harkness, 1986). Thus, mothers who display an interest in science may provide social contexts that engender children's interest in science.

Children, therefore, who observe mothers showing an interest in science or interact with mothers who display an interest in scientific topics, even if no such genuine interest exists, may still develop a view of science as something interesting and valuable. These findings support the need for future research into how fathers' interest in science might relate to children's interest in science and the differences in which mothers and fathers interact with children about scientific topics that might underlie the differences found in this dissertation.

These explanations may also explain the lack of gender differences found in the study. Mothers who demonstrate an interest in science may model that scientific interest for their daughters. Mothers who engage in scientific interests may help show that girls can be involved with science, which relates to girls' involvement with science learning (Lei et al., 2019; Rhodes et al., in press). The sample being predominantly mothers who volunteered for scientific studies may then relate to the lack of gender differences. As only one father was involved in the study, no comparisons could be made to further test this explanation, but it remains a potential avenue for further research.

This relation should be considered with some caution, as the measure for parent's interest in science had low reliability and only assessed interest in three common science topics. The measure assessed common topics of scientific interest and as such it was sufficient for this research as an initial step in examining the relation between parent's and children's interests in science (Takahashi & Tandoc, 2017). However, future research might benefit from using a more comprehensive measure of interest for parents to further explore this relation.

Limitations

This dissertation had several limitations. The study is cross-sectional. Longitudinal data would provide a more complete developmental trajectory of how interest and scientific thinking relate to one another, especially the trajectory regarding the development of epistemological understanding in relation to the development of scientific reasoning skills. Following children across age points would also provide a better understanding of how these relations change within participants across time.

This study compared only two age groups, 9-year-olds and 12-year-olds. Interest in science and scientific thinking skills both develop across a wide range of ages, with development occurring in earlier childhood, around ages 5 – 6, and into adolescence and adulthood (Feist, 2008). Investigation of such detailed developmental trajectories was beyond the scope of this dissertation, but future research would benefit from investigating interest in relation to children's epistemological understanding and scientific reasoning across a wider range of ages.

This study focused on interest in science as a general topic and does not directly investigate more content-specific interests. Interest may relate to reasoning skills differently when the content is targeted directly to the specific science topics that interest children, such as spaceships or bats (Azevedo, 2015). Examining the effects of interest on scientific thinking regarding specific content domains would provide further understanding of how children's interest in science relates to scientific thinking across different contexts.

This dissertation drew participants from only one geographic area and, more specifically, largely from the Developmental Psychology Participant Database. This sample population leaves open the potential risk for geographical and selection bias. As all families volunteered to be included in the subject pool, families in the database may have been more interested in science, or have a greater understanding of science, than a more general population. Additionally, the geographical region, being a university city, may have had a more scientifically knowledgeable population. These factors warrant consideration when generalizing the findings of the study, and future research should strive to include more geographically diverse samples.

The mediation analysis of the relation between children's interest in science, and the exploratory analysis of children's perception of mother's and father's interest in science, were made post-hoc. The present dissertation was not constructed to investigate mediation or suppression effects a priori. These offer two lines of future research. One, future research should explore how children's critical thinking and concepts of science mediates the relation between children's interest in science and epistemological thinking in greater detail. Two, future research should endeavor to investigate the role of parents with a larger sample of fathers and an expanded measure of parent's interest in science.

Despite these limitations, the proposed dissertation has both theoretical and practical implications. It is the first study to examine the relation between interest in science and both components of scientific thinking in depth in children age 9 and age 12, specifically utilizing a more comprehensive measure of interest in science (i.e., including measures for enjoyment, curiosity, value, and identification) to investigate relations to both aspects of scientific thinking (i.e., epistemological understanding and scientific reasoning). The dissertation shows that 9- and 12-year-olds' interest in science, in particular their identification with science, relates to their epistemological understanding but not their scientific reasoning. This dissertation sheds light onto the developmental trajectory of scientific thinking. The finding that 9-year-old children express similar epistemological understanding as 12-year-old children, but less sophisticated scientific reasoning suggests that the understanding of how knowledge is justified by evidence precedes the coordination of evidence to reason about one's theories. This dissertation also extends our knowledge of what characteristics of interest appear most important to developing scientific thinking skills during the ages of 9 and 12, with children's self-reported identification with science as a core characteristic related to more sophisticated epistemological understanding.

For practical applications, this dissertation's examination of how interest relates to the development of 9- and 12-year-olds' understanding of evidence and reasoning from evidence can inform educational interventions seeking to motivate children's learning of science and engineering practices during 4^{th} grade through middle school as detailed in the NGSS (National Research Council, 2013). Recent research shows that girls' identification as capable of participating in scientific activities relates to their persistence in science classrooms (Rhodes et al., in press). Incorporating identification with science into science lessons may then be a useful component to educational programs aimed at strengthening children’s understanding of evidence and knowledge. As interest related to a better understanding of evidence across multiple domains of knowledge and children’s reported critical thinking regarding media, developing interest in science may help improve children’s critical consumption of claims made in media and encountered online, an area especially difficult for 10- to 13-year-old children to navigate successfully (Wineburg et al., 2016). As a result, educational programs that engender an interest in science and allow children at age 9 to identify themselves as capable of scientific thinking may help children develop a more evidence-based epistemological understanding. The current dissertation did not assess educational interventions, and therefore the practical applications discussed above are interesting areas for future research.

Another practical application of this dissertation is that the scientific reasoning tasks used in this study examined scientific thinking in specific environmental science topics, such as water quality and livable environments. Environmental science is an important area in which to be scientifically literate. Climate change and resource scarcity will require people to interact with, or socially support, more scientifically complex technologies such as recycled water (Dolnicar & Hurlimann, 2011; Po, Kaercher, & Nancarrow, 2003). Scientific thinking is a vital skill in recognizing accurate scientific information, as people more accurately judge scientific claims when instructed about evidence supporting or refuting those claims (Van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017). This is especially important as prior information is exceptionally difficult to replace (Shtulman & Valcarcel, 2012) and influences how people reason about that content (Koslowski et al., 2008). The results from this study emphasize that a general interest in science is not sufficient in preparing children to face these issues. Therefore, while interest in science can potentially be an effective component of developing children's epistemological understanding about evidence, more specific instructions about scientific reasoning strategies and a focus on specific content may also be required to prepare children to become conscious consumers of scientific information.

Conclusion

This dissertation adds to our understanding of how interest in cognitively demanding topics such as science relates to developments in children's conceptual understanding and reasoning regarding those topics and more generally at age 9 and 12. Both 9 and 12-year-olds understood the importance of evidence in relation to knowledge at similar rates, but 12-year-olds performed better on the scientific reasoning tasks. As age differences were present for children's scientific reasoning but not their epistemological understanding, children's evidence-based epistemological understanding appears to develop first, and scientific reasoning develops at a later age. Thus, the development of scientific thinking in the ages of 9 and 12 may follow a trajectory of epistemological understanding preceding further development of scientific reasoning skills.

The findings suggest that children's interest in science relates to their epistemological understanding through their critical thinking at age 9 and 12 but does not relate to children's capability to solve problems that require them to reason scientifically. Children's interest in science related to their critical thinking in non-science topics (i.e., media consumption). Children's critical thinking positively related to higher levels of epistemological understanding. Thus, 9 and 12-year-olds' interest in scientific topics may help children develop their conceptualization of how their theories derive from, and are reinforced by, evidence.

Conversely, children's interest in science showed no relation to their scientific reasoning. Only children's age and academic achievement related to children's scientific reasoning, demonstrating that motivational aspects, such as curiosity about or identification with science, or affective aspects, such as enjoyment or valuing of science, associated with interest in science do not relate to the development of children's scientific reasoning skills. This finding suggests that children's interests do not relate to their capability in more demanding cognitive reasoning tasks. Therefore, success in such tasks may require development of cognitive processes, such as metamonitoring, or in school-based instructions between the ages of 9 and 12.

Measuring children's enjoyment, curiosity, value, and identification with science separately allowed for the investigation of how these characteristics influenced children's scientific thinking. Of the characteristics of interest, identifying with science as an area of interest or identifying as someone who is interested in science appears most related to developing epistemological understanding. Children who identified with science were more likely to report higher levels of epistemological understanding. Thus, children's epistemological understanding appears to be influenced by how children view themselves in relation to science at both 9- and 12-years-old.

Additionally, the findings associated with parental influences on children's interest in science support the theory that social factors affect the development of children's interest in science. Specifically, the results show that children who perceived their mothers as more interested in science were more likely to have a greater interest in science.

The findings of this dissertation support the theory that motivational and affective aspects such as interest in science relate to children's conceptual development, but not reasoning development at ages 9 and 12. Specifically, interest in science and concept of science relate to children's critical thinking that in turn relates to their epistemological understanding. Children's scientific reasoning appears to require more complex coordination of theory and evidence that develops more fully by age 12 and does not benefit from interest in science.

This dissertation also has practical applications. It can inform science education by elucidating the important, but peripheral, role interest in science plays in science education and what engendering interest can, and cannot, accomplish. These results indicate that interest in science relates to children's critical thinking and understanding of evidence at as young as 9-years-old, but that reasoning may require a more directed and explicit instruction. Additionally, children's interest in science may increase when mothers express interest in scientific topics. These findings have applications for school curricula that seek to utilize interest in science to foster scientific thinking and how the development of conceptual knowledge can relate to the development of applying this knowledge in situations that require complex reasoning or understanding scientific information (e.g., understanding climate change).

As a final point, it might be reasonable to look back on the core findings of this study to evaluate the role of interest in fostering creative channels to science learning. Interest in science has often been studied at either only a surface or qualitative level, and the current study provided a more detailed quantitative approach to investigating this construct. This dissertation showed that interest may influence the way people think about scientific information, but that this relation may only occur after one's interest crosses the threshold into a persistent individual interest in the topic. As such, future research may be able to foster and individual interest in science to involve children who may feel excluded from science in academic settings. This dissertation demonstrated that interest is different from academic achievement or involvement in academic activities. Thus, leveraging an individual interest in science may help children who do not have strong academic motivations become more capable of conceptualizing and understanding scientific information if we can tap into their interest in science and science-related activities.

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Tables & Figures

Table 1

Descriptive Statistics for All Continuous Variables

	Variable	Children age 9 years		Children age 12 years	
		Median	Mean (*SD*)	Median	Mean (*SD*)
1.	Children's interest in science[a]	3.63	3.64 (*0.56*)	3.63	3.62 (*0.62*)
2.	Children's self-efficacy[b]	3.80	3.75 (*0.67*)	4.00	3.95 (*0.65*)
3.	Children's critical thinking[c]	3.00	3.19 (*1.30*)	3.83	3.84 (*0.93*)
4.	Number of science topics of interest[d]	12.50	12.80 (*5.89*)	10.00	10.80 (*5.16*)
5.	Children's academic achievement[e]	4.50	4.25 (*0.69*)	4.50	4.43 (*0.62*)
6.	Child's science experience[f]	3.78	3.81 (*0.75*)	4.11	3.93 (*0.99*)
7.	Parent's interest in science[g]	2.33	2.47 (*0.36*)	2.33	2.38 (*0.50*)
8.	Parent's enjoyment of science[h]	3.67	3.71 (*0.77*)	4.0	3.74 (*1.01*)
9.	Parent's science self-sfficacy[i]	4.17	4.10 (*0.56*)	4.27	4.07 (*0.69*)

Note. Variables 1-4 were obtained through child-report, variables 5-9 were obtained from parent-report.
[a] Scores represent the average score out of a scale of 1 = *NO!* to 5 = *YES!*;
[b] Scores represent the average score out of a scale of 1 = *Not at all true* to 5 = *Very true*;
[c] Scores represent the average score out of a scale of 1 = *Never* to 6 = *Always*;
[d] Scores represent the summed score out of a scale of 0 to 24;
[e] Scores represent the average score out of a scale of 1 = *F* to 5 = *A*;
[f] Scores represent the average score out of a scale of 1 = *Never* to 7 = *Often*;
[g] Scores represent the average score out of a scale of 1 = *Not at all interested* to 3 = *Very interested*.

[h] Scores represent the average score out of a scale of 1 = *Strongly disagree* to 5 = *Strongly Agree*
[i] Scores represent the average score out of a scale of 1 = *Strongly disagree* to 5 = *Strongly Agree*

Table 2

Frequencies of Children's Concept of Science, Epistemological Reasoning, and Scientific Reasoning

Variable	Source	Level	9-year-olds Count (Percentage)	12-year-olds Count (Percentage)
Concept of science	*Initial Child Science Interview*	No response	2 (2.50%)	0 (0%)
		Identity	6 (7.50%)	5 (6.25%)
		Content	12 (15.0%)	12 (15.0%)
		Process	20 (25.0%)	23 (28.75%)
Epistemological understanding	*Jaime & Terry Questionnaire*	0	0 (0%)	1 (1.25%)
		1	3 (3.75%)	0 (0%)
		2	7 (8.75%)	5 (6.25%)
		3	5 (6.25%)	9 (11.25%)
		4	9 (11.25%)	6 (7.50%)
		5	7 (8.75%)	11 (13.75%)
		6	3 (3.75%)	1 (1.25%)
		7	4 (5.0%)	3 (3.75%)
		8	2 (2.50%)	4 (5.0%)
Scientific reasoning	*SRSI*	0	12 (15.0%)	5 (6.25%)
		1	7 (8.75%)	6 (7.50%)
		2	7 (8.75%)	5 (6.25%)
		3	2 (2.50%)	0 (0%)
		4	3 (3.75%)	3 (3.75%)
		5	1 (1.25%)	2 (2.50%)
		6	1 (1.25%)	3 (3.75%)

	7	0 (0%)	0 (0%)
	8	1 (1.25%)	0 (0%)
	9	2 (2.50%)	5 (6.25%)
	10	4 (5.0%)	11 (13.75%)

Note. *SRSI = Science Reasoning Semi-Structured Interview*. All percentages are based on the full sample (n = 80). For concept of science, values represent child's definition of science. For epistemological understanding, values represent each child's summed scores in the *Jaime & Terry Questionnaire* across the four domains. For scientific reasoning, values represent the sum of child scores for both problems in the reasoning task (i.e., water and planets).

Table 3

Summary of Intercorrelations Between Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Epistemological understanding	-	.25*	.26*	.09	.06	-.05	.29**	.15	-.003	.27*	.36**	.30**	-.03
2. Scientific reasoning		-	-.006	.30**	-.09	.14	.07	.34**	.10	.12	.05	-.18	.13
3. Science interest			-	-.045	-.11	-.16	.68**	.017	.008	.15	.42**	.58**	-.21†
4. Age				-	.024†	.15	.12	.13	.051	.19	.27*	-.16	.09
5. Gender					-	.11	-.01	-.20	.16	-.062	-.10	.22*	-.21†
6. Ethnicity						-	-.23*	-.13	.021	-.058	.051	-.15	.07
7. Child Self-efficacy							-	.24*	.082	.21†	.30**	.46**	.01
8. Academic achievement								-	.31**	.13	.039	-.065	.49**
9. Science experience									-	-.093	.023	.016	.36**
10. Concept of science										-	.20†	.048	-.03
11. Critical thinking											-	.28*	.02
12. Topics of interest												-	-.31**
13. SES													-

Note. † = *p*-value < .10, * *p*-value < .05, ** *p*-value < .01, *** = *p*-value < .001.

Table 4

Ordinal Regression Coefficients Relating Interest in Science and Epistemological Understanding and Post-Hoc Mediation Analysis

		Epistemological Understanding							
		Estimate	SE	Wald	*p*	R^2	ΔR^2	95% CI	
								Low	Up
Model 1	Children's interest in Science	0.73	0.34	4.47	0.03	0.06		0.05	1.40
Model 2	Children's interest in Science	0.39	0.38	1.11	0.29	0.13	0.07	-0.34	1.13
	Critical thinking	0.47	0.19	5.97	0.02			0.09	0.85
Model 2	Children's interest in science	-0.69	0.54	1.60	0.21	0.28	0.11	-1.76	0.38
	Critical thinking	0.47	0.20	5.71	0.02			0.08	0.86
	Self-efficacy	0.73	0.42	3.03	0.08			-0.09	1.56
	Science topics of interest	0.08	0.05	2.78	0.09			-0.01	0.17
	Concept of science – *No response* [a]	-2.85	1.44	3.89	0.049			-5.7	-0.02
	Concept of science – *Identity* [a]	-1.27	0.64	3.92	0.048			-2.52	-0.01
	Concept of science – *Content* [a]	0.29	0.46	0.41	0.52			-0.60	1.18

[a] Reference group is concept of science - *Process*.

Table 5

Ordinal Regression Coefficients Relating Scientific Reasoning and Interest in Science

		Scientific Reasoning							
		Estimate	SE	Wald	p	R^2	ΔR^2	95% CI	
								Low	Up
Model 1	Children's interest in science	0.57	0.55	1.09	0.30	0.21		-0.48	1.67
	Critical thinking	-0.18	0.19	0.00	0.38			-0.58	0.22
	Self-efficacy	-0.13	0.41	1.40	0.77			-0.98	0.78
	Science topics of interest	-0.08	0.05	2.42	0.12			-0.17	0.02
	Academic achievement	0.92	0.34	7.18	0.01			0.25	1.61
	Age [a]	-1.17	0.46	6.46	0.01			-2.07	-0.27
Model 2	Child interest x age [b]	-0.07	0.27	0.08	0.77	0.21	0.002	-0.51	0.38

[a] Reference group is 12-year-old age group.

[b] Model 2 is the same as model 1 with the interaction term introduced.

Table 6

Ordinal Regression Coefficients Relating the Four Characteristics of Children's Interest in Science and Children's Epistemological Understanding

		Epistemological Understanding						
		Estimate	SE	Wald	*p*	R^2	95% CI	
							Low	Up
Model 1	Science enjoyment	-0.39	0.45	0.60	0.52	0.31	-1.57	0.79
	Science curiosity	-0.49	0.57	0.76	0.38		-1.60	0.62
	Science value	-0.28	0.56	0.26	0.61		-1.39	0.82
	Science identification	1.78	0.61	8.66	0.003		0.60	2.97
	Critical thinking	0.45	0.23	3.80	0.05		-0.00	0.89
	Concept of science – *No response* [a]	-3.11	1.51	4.26	0.04		-6.07	-0.16
	Concept of science – *Identity* [a]	-1.34	0.64	4.47	0.03		-2.59	-0.10
	Concept of science – *Content* [a]	0.23	0.46	0.26	0.61		-0.66	1.13

[a] Reference group is 12-year-old age group.

Table 7

Regression Coefficients Relating Mother's Interest in Science and Children's Interest in Science

		Children's interest in science							
		β	t	p	R^2	$R^2_{adj.}$	ΔR^2	95% CI	
								Low	Up
Model 1	Mother's interest in science	0.07	0.66	0.51	0.09			-0.18	0.43
Model 2	Mother's interest in science	0.16	1.50	0.14	0.20	0.18	0.11	-0.4	0.52
	Child's perception of parent interest	0.45	4.31	<0.001				0.08	0.22
Model 3 [a]	Mother's interest x Children's interest in science	-0.09	-0.81	0.42	0.21	0.17	0.01	-0.81	0.42
Model 4	Mother's interest in science	0.11	1.01	0.31	0.25	0.22	0.05	-0.11	0.45
	Child's perception of mother's interest	0.41	3.62	0.001				0.13	0.44
	Child's perception of father's interest	0.14	1.17	0.24				-0.07	0.28

[a] Model 3 is the same as model 2 with the interaction term introduced.

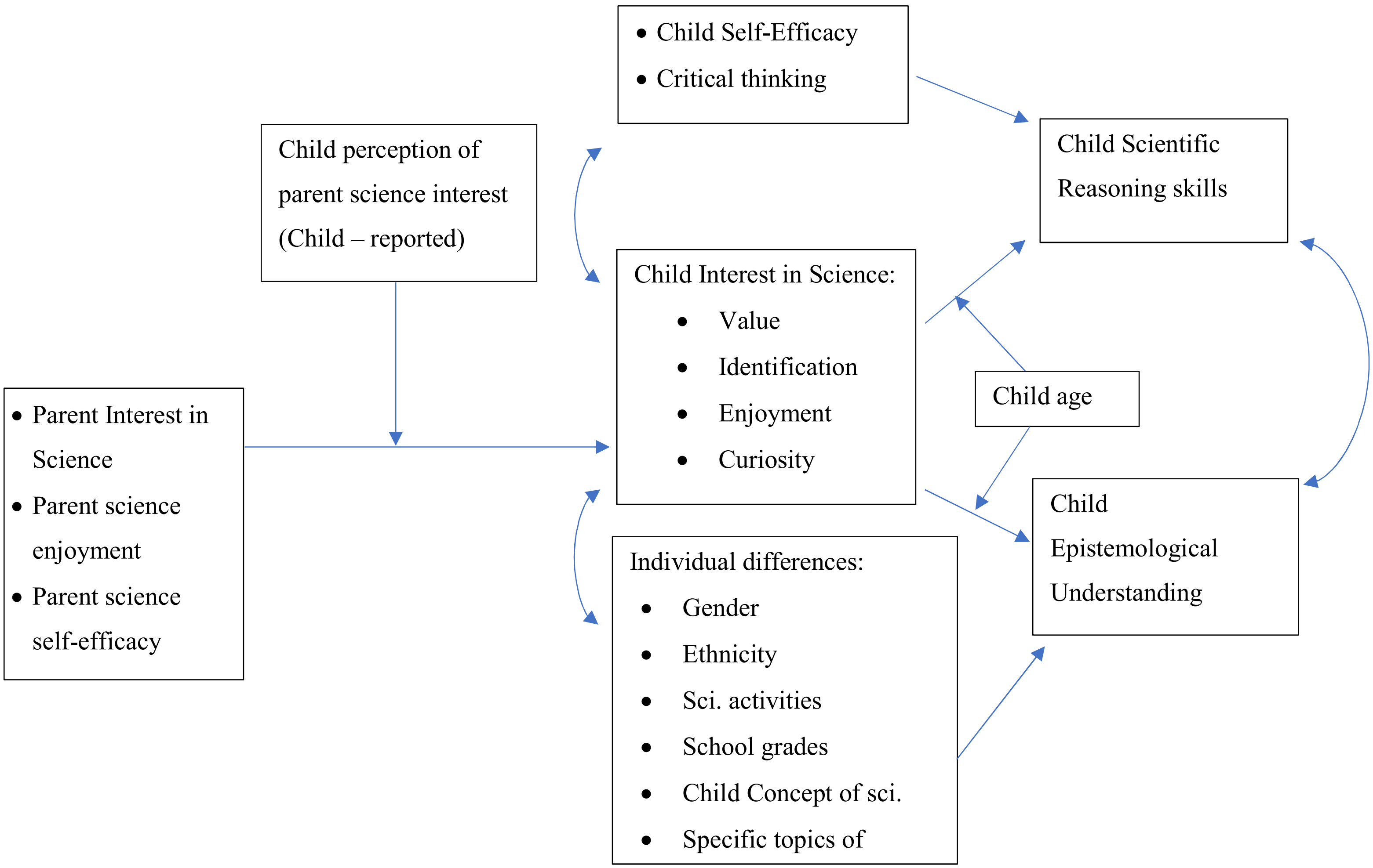

Figure 1. The conceptual model of how children's interest in science influences epistemological understanding and scientific reasoning skills.

Child Participation: ~ 1 hour

Informed Consent (Parent and child present)

Initial child science Interview by PI (Appendices A and B)

Child Science Topics Interest Survey (Appendix C)

Child Interest in Science Questionnaire (Appendix D)

Self-efficacy and Critical Thinking questionnaire (Appendix E and F)

(On computer) Epistemological Understanding Assessment (Appendix G)

Science Reasoning Task & Interview (Appendices H and I)

Thanked, compensated, and dismissed.

Parent Participation ~17 min.

Informed Consent (Parent and child present).

Family Demographics Questionnaire (Appendix J)

Child Science Experience Questionnaire (Appendix K)

Child School Performance Questionnaire (Appendix L)

Parent Science Interest, Self-Efficacy, & Enjoyment Questionnaire (Appendix M)

Thanked, compensated, and dismissed.

Figure 2. The study procedure, illustrated sequentially, for both parent and child beginning at Informed Consent and ending with Thanking and Dismissal

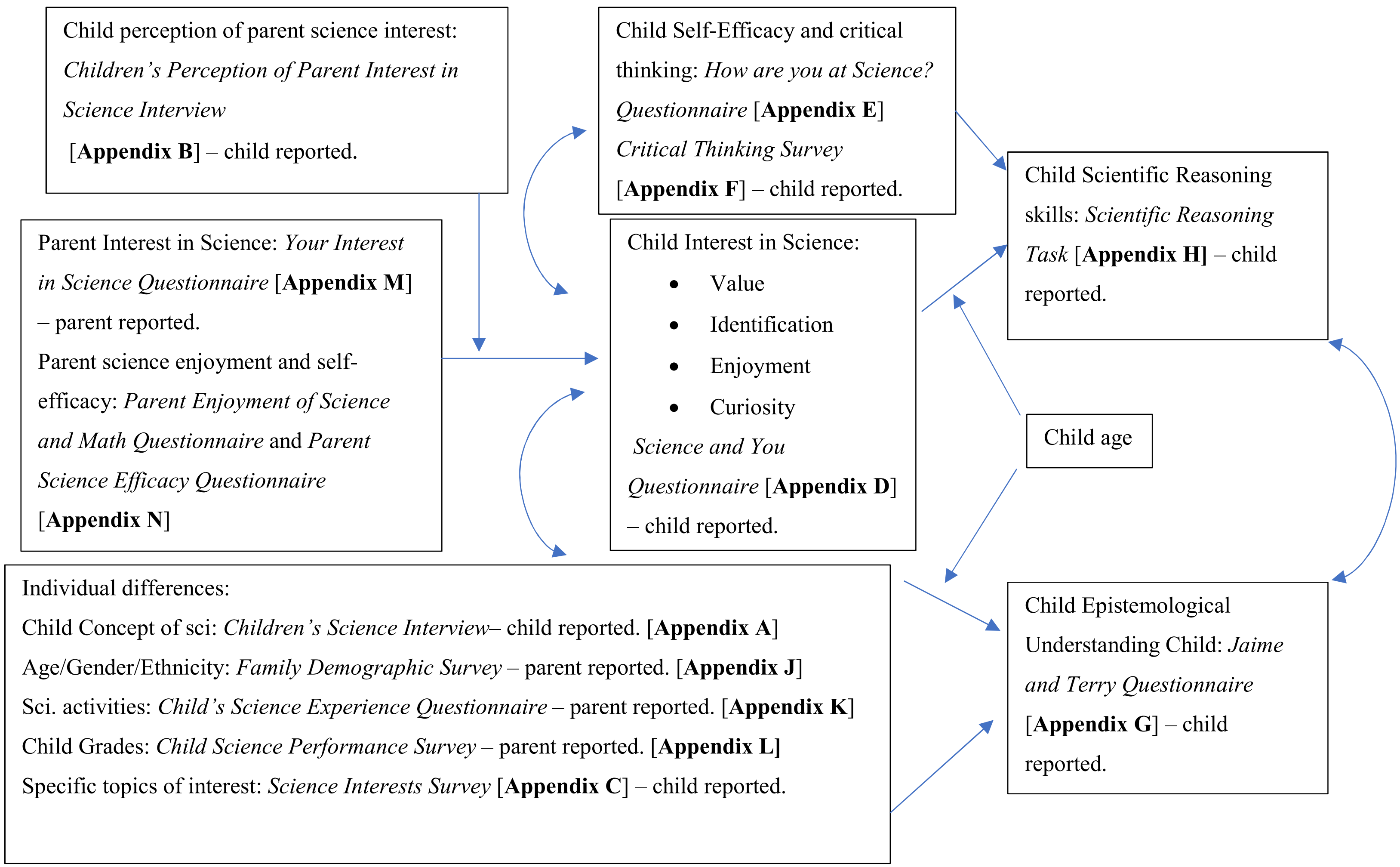

Figure 3. The conceptual model identifying the Appendix in which each measure can be found corresponding to their respective construct in the model.

Appendices

Appendix A

Child's Science Interview

Open-ended Question start: *Investigator* "To begin I would like to ask you a few questions."

NOTE: *use follow-up question as necessary if child provides uninformative response (e.g., "I don't know" or nonverbal gesture).*

Q#	Child Science Interview items
1	"Can you tell me what is science?"
Follow-up	"If you had to guess, what would say?"
Follow-up	"If you had to, how would you describe science to someone?"
2	"Can you give me an example of science?"
Follow-up	"If you had to guess, what would say?"
Follow-up	"What about that makes it 'science'?"
3	"Why do you think people might do science experiments?"
Follow-up	"If you had to guess, what would say?"
Follow-up	"Why would you want to do a science experiment?"

For coding, see Appendix O Coding Scheme: *Concepts of Science*

Appendix B

Children's Perception of Parent Science Interest Interview

Semi-structured Interview begin: *Investigator* "Now I would like to ask you a few questions about what your parents think about science."

NOTE: Use follow-up question in case child provides a general "yes" response.

Q#	Questions	Answers		
1	Do you ever talk to your mom or dad about science or science-related things?	__Mom	__Dad	__Both
Follow-up	Do you talk to your mom, or dad, or both?	__Mom	__Dad	__Both
Follow-up	"How much do you talk to your [parent] about science or science-related things?"	___ a lot	___a little	

NOTE: follow up questions only asked about parents who child mentions talking to about science.

Mother Follow-up items		
Does your mom think science or science-related things are interesting?	___Yes	___No
If yes… How interesting does your mom think they are?	___ a lot	___a little
Father Follow-up items		
Does your dad think science or science-related things are interesting?	___Yes	___No
If yes… How interesting does your dad think they are?	___ a lot	___a little

For coding see Appendix A.8 Coding Scheme: *Child Perception of Parent Interest*

Appendix C

Science Topics Survey

Instructions: We would like to know more about what scientific things interest you. Can you tell us what things you are interested in learning more about by writing down the number under the face that best shows how you feel about each topic in the space next to the topic?

1 2 3

1. _______Planets
2. _______Video games
3. _______Space travel
4. _______The sun
5. _______Black holes
6. _______The oceans
7. _______Earthquakes
8. _______Storms
9. _______Climate change
10. _______Fossils
11. _______Health
12. _______Volcanoes
13. _______Wild animals
14. _______Healthy eating
15. _______Music
16. _______Evolution
17. _______Plants
18. _______Germs
19. _______Computers

20. ______Robots
21. ______Airplanes
22. ______Solar power
23. ______Programming
24. ______Gravity
25. ______Sports
26. ______Nuclear energy
27. ______Electricity
28. ______Magnets

Appendix D

Child's Interest in Science Questionnaire

Instructions: We would like to know how you feel about science. Please tell us how much you agree with each of these sentences. Circle **NO!** if you strongly disagree, circle **no** if disagree a little, circle **maybe** if you are not sure, circle **yes** if you agree a little, and circle **YES!** If you strongly agree. There are no right or wrong answers, we only want to know what you think about these things.

Subscale	#	Question	Answers				
General Interest[a]	1	It is important to me to be a good scientist.	NO!	no	maybe	yes	YES!
	2	I enjoy working on science problems.	NO!	no	maybe	yes	YES!
	3	Science is one of the things that is important to me personally.	NO!	no	maybe	yes	YES!
	4	I would even give up some of my spare time to learn new topics in science.	NO!	no	maybe	yes	YES!
	5	While working on a science problem, it sometimes happens that I don't notice time passing.	NO!	no	maybe	yes	YES!
	6	I think like a science type person.	NO!	no	maybe	yes	YES!
	7	Other people think I'm good at doing science.	NO!	no	maybe	yes	YES!
	8	I am the type of person who could work as a scientist someday.	NO!	no	maybe	yes	YES!

	9	Learning about science would be very easy for me in school.	NO!	no	maybe	yes	YES!
	10	No matter how hard I try, I am confused by science. (R)	NO!	no	maybe	yes	YES!
	11	I often think, "I will fail" when a science activity seems hard. (R)	NO!	no	maybe	yes	YES!
	12	I am bad at doing science activities. (R)	NO!	no	maybe	yes	YES!
	13	When I think about the word "science," I have a bad feeling. (R)	NO!	no	maybe	yes	YES!
	14	I feel uncomfortable when other kids talk to me about science. (R)	NO!	no	maybe	yes	YES!
	15	I have a good feeling when I think about science in school.	NO!	no	maybe	yes	YES!
	16	It is important for me to learn about science over summer vacation.	NO!	no	maybe	yes	YES!
Identification[b]	17	I am a person who thinks like a scientist.	NO!	no	maybe	yes	YES!
	18	I often investigate science topics so that I can understand how things work.	NO!	no	maybe	yes	YES!
	19	I often investigate science topics in my free time so that I can learn more about it.	NO!	no	maybe	yes	YES!
Curiosity[b]	20	Outside of science class, I often wonder about science.	NO!	no	maybe	yes	YES!
	21	I am curious to learn how the body works.	NO!	no	maybe	yes	YES!

	22	I like to mess around with new technology.	NO!	no	maybe	yes	YES!
	23	I enjoy exploring new activities about science in school.	NO!	no	maybe	yes	YES!
	24	It is cool to learn new things about science in school.	NO!	no	maybe	yes	YES!
	25	Everywhere I go, I am looking for new activities about science.	NO!	no	maybe	yes	YES!
	26	Wherever I go, I am interested in discovering new facts about science.	NO!	no	maybe	yes	YES!
	27	I get excited about discussing science in school.	NO!	no	maybe	yes	YES!
Enjoyment[c]	28	I usually have fun when I am learning about science.	NO!	no	maybe	yes	YES!
	29	I am happy doing science problems.	NO!	no	maybe	yes	YES!
	30	I enjoy science class.	NO!	no	maybe	yes	YES!
	31	Science problems are fun challenges.	NO!	no	maybe	yes	YES!
	32	I enjoy learning new things about science.	NO!	no	maybe	yes	YES!
Valuing	33	I think what I learn in science class is important.	NO!	no	maybe	yes	YES!
	34	I think science is a useful subject.	NO!	no	maybe	yes	YES!
	35	I find science interesting.	NO!	no	maybe	yes	YES!

[a]Measures adapted from Marsh et al., (2005); [b]Measures adapted from Bathgate et al., (2014); [c]Measures adapted from the Achievement Emotions Questionnaire (AEQ, Ainley & Ainley, 2011; Pekrun et al., 2011); [d]Measures adapted from Bong (2001).

Appendix E

Child Self-Efficacy Questionnaire

Instructions: We would like to know about how confident you are at doing science activities. Please tell us whether these sentences are **not at all true**, **not true**, **maybe true**, **true**, or **very true**. Again, there are no right or wrong answers, we only want to know what you think.

Q#	Question	Answer				
1	I can understand even the hardest material in science if I try.	Not at all true	Not True	Maybe True	True	Very True
2	I can do almost all of the work in science if I do not give up.	Not at all true	Not True	Maybe True	True	Very True
3	I'm certain that I can do an excellent job on the problems and tasks assigned for science class.	Not at all true	Not True	Maybe True	True	Very True
4	I know that I will be able to learn the material for science class.	Not at all true	Not True	Maybe True	True	Very True
5	I am confident that I will receive a good grade in science class this year.	Not at all true	Not True	Maybe True	True	Very True

Note. Measures adapted from Bong (2001).

Appendix F

Child Critical Thinking Survey

Instructions: We would like to know about how you think about the media you watch, like television shows, internet videos, or advertisements. Please tell us how often you do the things in the sentences, between **never** and **always**. There is no right or wrong answer, we want to know what you think.

Q#	Question	Never					Always
1	I think about the purpose behind a message I see on television.	1	2	3	4	5	6
2	I think about who created the message I see on the ad.	1	2	3	4	5	6
3	I think about what the people who made the media message want me to believe.	1	2	3	4	5	6
4	I think about the things that the advertisers do to get my attention.	1	2	3	4	5	6
5	I think about whether the things that the advertisers want me to do are good for me.	1	2	3	4	5	6
6	I try and think about how true or false an advertisement is.	1	2	3	4	5	6

Note. McLean, Paxton, & Wertheim (2016)

Appendix G

Jaime and Terry Questionnaire (Epistemological Understanding Assessment)

Instructions: Here are a few stories about Jaime and Terry. Jaime and Terry disagree on some things. We would like to know what you think about their disagreements. Can you tell us by answering the questions that appear under each story?

Jaime says warm summer days are the nicest. Terry says cool summer days are the nicest.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Jaime says the stew is spicy. Terry says the stew is not spicy at all.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Jaime says that people should get married in the afternoon. Terry says that people should get married in the evening.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

______One could be more right ______One could not be more right than the other

Jaime thinks that the first song they listened to was better. Terry thinks that the second song they listened to was better.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

______One could be more right ______One could not be more right than the other

Jaime thinks that the first painting they saw was better. Terry thinks the second painting they saw was better.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

______One could be more right ______One could not be more right than the other

Jaime thinks that the first book they read was better. Terry thinks that the second book they read was better.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

______One could be more right ______One could not be more right than the other

Jaime thinks that people should take care of themselves. Terry thinks that people should work together to take care of each other.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

    ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

    ______One could be more right ______One could not be more right than the other

Jaime thinks that lying is wrong. Terry thinks that lying is OK in certain situations.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

    ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

    ______One could be more right ______One could not be more right than the other

Jaime thinks that the government should limit the number of children families can have to keep the population from getting too big. Terry thinks families should have as many children as they choose.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

    ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

    ______One could be more right ______One could not be more right than the other

Jaime believes one book’s explanation for how children learn to read. Terry believes another book’s explanation for how children learn to read.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Jaime believes one reason for why people commit crime. Terry believes a different reason for why people commit crime.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Jaime believes one book’s explanation for the cause of the Revolutionary War. Terry believes a different book’s explanation for the cause of the Revolutionary War.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Jaime believes one explanation for how the brain works. Terry believes a different explanation for how the brain works

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Jaime believes one book's explanation for what atoms are made up of. Terry believes a different book's explanation for what atoms are made up of.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Jaime believes one explanation for changing weather. Terry believes a different explanation for changing weather.

1. Can only one of their views be right, or could both have some rightness? (Please check one)

   ______Only one right ______Both could have some rightness

2. If both can be right, can one view be better or be more right than the other? (Please check one)

   ______One could be more right ______One could not be more right than the other

Appendix H

Scientific Reasoning Task

Scientific Reasoning Task instructions

Introduction to task. “I was wondering if you could help me. I have been trying to find out why some cities have dirty water and some cities have clean water. To help, first we need to find out what makes a difference to whether a city’s water is dirty or clean.”

Task instructions. [*Researcher displays stack of 8 records on 8” x 11” paper, see Figure G1*] “I have some records here that tell me about some things that I think might make a difference to whether a city has dirty or clean water. I would like you to look through them [*researcher points to graphs on records*] to find something that makes a difference to whether a city has dirty or clean water. Do you have any questions?

Task Start. “Great! I am going to work over here, why don’t you start to see what makes a difference. If you think you have found something, let me know.” [*Investigator leaves stack of records on table with child and sits at another table in the room*]

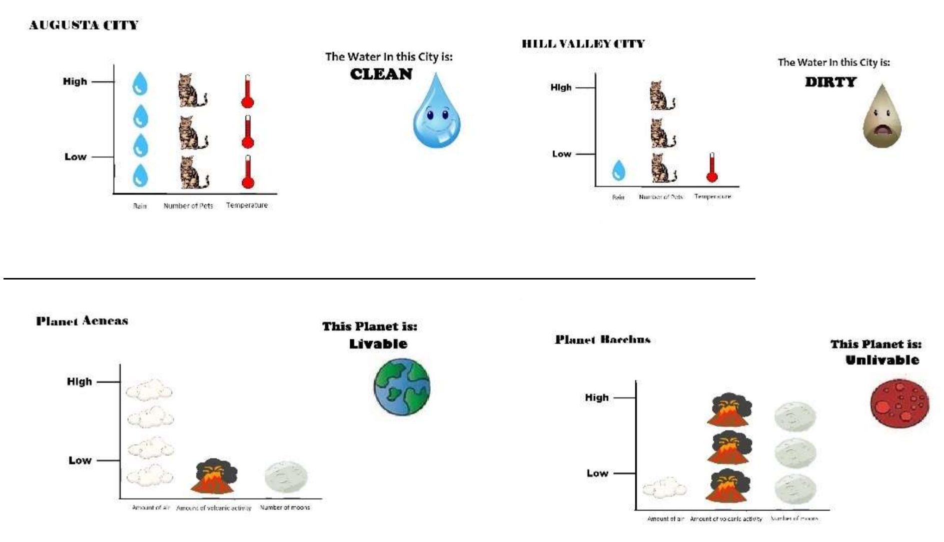

Figure G1. Examples of records for water and planet tasks.

Table H1

Full list of Water Records

Record #	City Name	Rain	Pets	Temperature	Outcome
1	Augusta	Hi	Hi	Hi	Clean
2	Orotown	Hi	Hi	Lo	Clean
3	Glenfield	Hi	Lo	Lo	Clean
4	Orotown	Hi	Lo	Hi	Clean
5	Mountwood	Lo	Lo	Hi	Dirty
6	Glenfield	Lo	Hi	Hi	Dirty
7	Hill Valley	Lo	Hi	Lo	Dirty
8	Pinedale	Lo	Lo	Lo	Dirty

Note. All records will be presented to child participant in a random order.

Table H2

Full list of Planet Records

Record #	Planet Name	Air	Volcanoes	Moons	Outcome
1	Diana	Hi	Hi	Hi	Livable
2	Ceres	Hi	Hi	Lo	Livable
3	Aeneas	Hi	Lo	Lo	Livable
4	Telesto	Hi	Lo	Hi	Livable
5	Janus	Lo	Lo	Hi	Unlivable
6	Bacchus	Lo	Hi	Hi	Unlivable
7	Minerva	Lo	Hi	Lo	Unlivable

8	Iovis	Lo	Lo	Lo	Unlivable

Scientific Reasoning Semi-Structured Interview

Instructions: Begin interview when child signals they have found a causal variable. [*NOTE TO INVESTIGATOR*: use follow-up question only if child provides a confounded or uncontrolled comparison for justification].

Q#	Scientific Reasoning Semi-Structured Interview (SRSI)
1	What thing are you looking at" [*do not proceed until child has indicated a variable*]
2	Does that make a difference?
3	How do you know?
Follow-up	What if someone were to say that they don't think it was [*child's identified variable*] that made a difference and that it was actually [*confound variable*]? What would you tell them?
4	What do you think would happen in this city if [*child's identified variable*] went down?

5	What do you think would happen in this city if [*child's identified variable*] went up?
6	If someone in the city were to come to you and say "We want to start a program to deal with [identified variable] because we think it will make our water cleaner," what would you say?

Note. Task adapted from Jewett and Kuhn (2016). To view coding of the SRSI, see Appendix A.8 Coding Scheme: *Scientific Reasoning*.

Appendix I

Post-Task Interview

Q#	Child Post-Task Interview items
1	"Is (*chosen variable*) good or bad?"
Follow-up	"Why do think so?"
2	"Is (*unrelated variable*) good or bad?"
Follow-up	"Why do you think so?"
3	"Jaime, from before, was helping me earlier and said that is was not (*chosen variable*), but *(alternate variable)*, could they be somewhat right too?"
Follow-up (if child responds yes)	"Could your or Jaime be more or less right than the other?"

Appendix J

Family Demographic Survey

Instructions: We would like to know some background information about your family. The following questions ask about you and your child's age, gender, and family information. Please fill in the blanks and check the answers that best apply to your family and your child participating in this study.

Your Child

1. Child's name? _________________________
2. What is your child's gender?

   ____male   ____female
3. What is your child's birthdate? ______/______/_____ (Month / Day / Year)
4. What is your child's ethnic background?

   ____ White/European American   ____Black/African American   ____Native American

   ____ Hispanic/Latino/a   ____Asian/Asian American   _____Multiethnic

   ____Other (please specify) ____
5. What school does your child attend? ____________________________________
6. What grade is your child in?

   ____ Grade 3   ____ Grade 4   ____ Grade 5   ____ Grade 6   ____ Grade 7

Your information

7. What is your relation to your child?

____ Mother ____Father ____Other (please specify)

____

8. What is your age?

____18-24 years old ____25-34 years old ____35-44 years old ____45-54 years old

9. What is your ethnic background?

____ White/European American ____Black/African American ____Native American

____ Hispanic/Latino/a ____Asian/Asian American _____Multiethnic

____Other (please specify) _____________________________________

10. What is your marital status?

_____ Married _____ Single _____ Separated _____ Divorced _____ Widowed

11. What is your occupation? __________________________

12. What is your highest level of education completed?

_____ 8th grade

_____ Some high school

_____ High school

_____ Some vocational school or college

_____ Four-year college

_____ Graduate degree (medical, law, graduate school, etc).

13. What is your family's annual household income?

_____ Less than $30,000

_____ Between $30,000 and $50, 000

_____ Between $50,000 and $100, 000

_____ More than $100, 000

_____ Prefer not to answer

Spouse's information

Instructions. We would like to know some information about your spouse as well. If you have a spouse, please answer the questions below as best you can.

14. What is your spouse's relation to your child?

    ____ Mother ____Father ____Other (please specify)

    ____

15. What is your spouse's age?

    ____18-24 years old ____25-34 years old ____35-44 years old ____45-54 years old

16. Spouse's ethnic background?

    ____ White/European American ____Black/African American ____Native American

    ____ Hispanic/Latino/a ____Asian/Asian American _____Multiethnic

    ____Other (please specify) _____________________________________

17. What is your spouse's occupation? _________________________

18. What is your spouse's marital status?

    _____ Married _____ Single _____ Separated _____ Divorced

19. What is your spouse's highest level of education completed?

_____ 8^{th} grade

_____ Some high school

_____ High school

_____ Some vocational school or college

_____ Four-year college

_____ Graduate degree (medical, law, graduate school, etc).

Appendix K

Child's Science Experience Survey

Instructions: We would like to know about the experiences your child has with science. The following questions ask what science-related activities your child does outside of school. Please answer as best you can.

1. Please indicate which of the below activities your child participates in by selecting either **YES** or **NO**. (Select all that apply).

Does your child…

Participate in a science fair?	Yes	No
Go to a science museum?	Yes	No
Play sports?	Yes	No
Go to a science summer camp?	Yes	No
Read books for fun?	Yes	No
Play a musical instrument?	Yes	No
Watch science-related TV?	Yes	No
Visit science-related websites?	Yes	No
Play video games	Yes	No

2. Please rate how often your child takes part in the activities listed below by circling a

number between (1) **Never** and (7) **Often**. If your child does not participate in the listed activity please circle (1).

How often does your child …	Never			Occasionally			Often
Participate in a science fair	1	2	3	4	5	6	7
Go to a science museum	1	2	3	4	5	6	7
Play sports?	1	2	3	4	5	6	7
Go to a science summer camp?	1	2	3	4	5	6	7
Read books for fun?	1	2	3	4	5	6	7
Play a musical instrument?	1	2	3	4	5	6	7
Watch science-related TV	1	2	3	4	5	6	7
Visit science-related websites	1	2	3	4	5	6	7
Play video games	1	2	3	4	5	6	7

Appendix L

Child's School Performance Survey

Instructions: We would like to know how your child's school performance in five areas (Mathematics, Reading, Writing, Social Sciences, Overall). Based on your child's homework, report cards, and test scores, please indicate what grade your child generally receives in science class.

1	2	3	4	5
F	D	C	B	A

____ Mathematics ____Reading ____Writing

____Social Science ____Overall Achievement

Appendix M

Your Interest in Science Questionnaire

Instructions: We would like to know about your interests in some science-related topics. There are no right or wrong answers, we wish to know what you think. Please indicate if you are **not at all interested**, **moderately interested**, or **very interested** in the topics listed below. Please write the number that best describes your interest in the listed science topics in the space next to each topic.

Not at all interested	Moderately interested	Very interested
1	2	3

_____ Space Exploration.

_____ New scientific discoveries.

_____ New technologies.

Appendix N

Parent Enjoyment and Self-efficacy Questionnaires

Parent Science Efficacy Questionnaire

Instructions: We would like to know your feelings about science and math in school and how well you feel you can help with your child's science and math learning. For the questions below please indicate how much you agree with the following statements about your child's learning.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I feel confident that I can help my child learn science skills.	1	2	3	4	5
I feel confident in providing developmentally-appropriate science activities for my child.	1	2	3	4	5
I know the science skills my child should be learning at his/her age.	1	2	3	4	5
I feel confident that I can help my child learn math skills.	1	2	3	4	5
I feel confident in providing developmentally-appropriate math activities for my child.	1	2	3	4	5

I know the math skills my child should be learning at his/her age.	1	2	3	4	5
I feel confident that I can help my child learn reading and writing skills.	1	2	3	4	5
I feel confident in providing developmentally-appropriate reading and writing activities for my child.	1	2	3	4	5
I know the reading and writing skills my child should be learning at his/her age.	1	2	3	4	5

Parent Enjoyment of Science and Math Questionnaire

Instructions: We would like to know your feelings about science and math learning. For the questions below please indicate how much you agree with the following statements about your child's learning.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
When I was in school, I was good at science.	1	2	3	4	5
I find science enjoyable.	1	2	3	4	5

When I was in school, I enjoyed science.	1	2	3	4	5
When I was in school, I was good at math.	1	2	3	4	5
I find math enjoyable.	1	2	3	4	5
When I was in school, I enjoyed math.	1	2	3	4	5

Appendix O

Coding Schemes

Measure	**Code Description**
Concepts of Science	Conceptual Level 1. Naïve 2. Intermediate 3. Advanced
Perception of Parents Interest in Science	Parent Interest Level 1. Low 2. Medium 3. High
Epistemological Understanding	Epistemological Understanding 1. Absolutist 2. Multiplist 3. Evaluativist

Scientific Reasoning	Scientific Reasoning Level
	1. Level 0 2. Level 1 3. Level 2 4. Level 3 5. Level 4 6. Level 5

Coding Scheme: *Children's Concept of Science*

-- Children's responses to the *concept of science* interview questions (see Appendix A) will focus on children's conceptual understanding of science, assessing children's concept of science as concrete fact or testing of hypotheses.

-- This measure will be coded on 4-point scale from 0 (no response) to 3 (process), focusing on children's conceptual understanding of the nature of science as pertaining to the testing of ideas and interpreting information to gather explanations over concrete activities or factual information. The coding was adapted from prior work by Sobel & Letourneau (2015).

Table L1

Levels of Children's Concept of Science

Concept Level	Coding	Example

No response	Child cannot respond or define science in any fashion.	"I don't know." / "*Silence*."
Identity	Child defines science as recursively as "science" or an unknow activity.	"Science is science." / "Science is what scientists do."
Content	Child defines science as science-related activities or content	"Science is electricity." / "Science is mixing chemicals because of the chemicals."
Process	Child defines science as a process of finding answers, knowledge, or testing hypotheses.	"Science is doing experiments." / "Science is finding out new things or testing stuff."

Coding Scheme: *Child Perception of Parent Science Interest*

-- Children's perception of parent science interest is coded on a 3-point scale corresponding to the structured *Child Perception of Parent Science Interest Interview* (see Appendix B) ranging from 1 (low) to 3 (high).

Table L2

Levels of Perceived Parent Interest in Science

Level of Perceived interest	Coding
Low	Parent does not talk to child about science / Child responds parent does not think science is interesting.
Medium	Parent talks to child about science. Child responds that parent finds science interesting “a little”.
High	Parent talks to child about science. Child responds that parent finds science interesting “a lot”.

Coding Scheme: *Epistemological Understanding Level*

-- Children's epistemological understanding will be coded based on children's responses to each of the *Jaime and Terry* stories, see Appendix F.

-- The 15 stories correspond to four domains (3 items in each domain) differing in subjectivity. Domains and stories are represented in Table L3.

-- Each response will be coded on a 3-point scale as (0) absolutist, (1) multiplist, or (2) evaluativist, for detailed item-based coding see Table L4. Each domain will receive one score according to the predominant epistemological level reported in that domain. Domains will then be averaged to compute a general level of epistemological understanding.

Table O3

List of Items Separated by Domain

Aesthetic Judgment
Whether the first or second song is better. Whether the first or second painting is better. Whether the first or second book is better.
Value Judgment
People should take care of themselves or people should work together. Lying is always wrong or lying OK in some circumstances. The number of children should be limited or families should be as big as people want.
Social World Truth
Whether one book's explanation for how children learn to read is better than the other.

	One reason for why people commit crime opposed to a different reason.
	Whether one book's cause for the Crimean war is better than the other.
Physical World Truth	
	One explanation for how the brain works opposed to a different explanation.
	Which book's explanation for what makes up atoms is better.
	One explanation for changing weather opposed to a different explanation.

Table L4

Epistemological Understanding Item Coding

Level of Epistemological Understanding (Coding)	Child response to Q #1[a]	Child Response to Q #2[b]
Absolutist (0)	Only one right	-
Multiplist (1)	Both could be right	One could NOT be more right
Evaluativist (2)	Both Could be right	One could be more right

Note. "-" indicates that question is not asked, thus no response is coded at this level. [a]Q #1 = Can only one of their views be right, or could both have some rightness? [b]Q #2 = If both could be right, can one view be better or be more right than the other?

Coding Scheme: *Scientific Reasoning Level*

-- Children's scientific reasoning skills will be coded from their responses to the **Scientific Reasoning Semi-Structured Interview** (SRSI).

-- The 6-point scale from 0 to 5 is designed to assess how children infer conclusions from multiple sources of data, and justify these inferences with evidence (Jewett & Kuhn, 2016). See Table L5 for detailed coding of the six levels. See Appendix G for SRSI script.

Table L5

Scientific Reasoning Level Coding for the Scientific Reasoning Semi-Structured Interview (SRSI)

Level	Coding Definition	Example
0	Child justifies choice with belief alone without reference to evidence / child fails to produce any choice. (**SRSI Q1** / **Q3**)[a]	"Rain would make a difference because it washes away the bad water"
1	Child justifies choice with reference to single case/incorrect interpretation of multiple cases. (**SRSI Q3 & Follow-up**)[a]	If you look here (points to one case) you can see recycled water makes water clean. *Investigator – How do you know it is recycled water and not one of these other things that also differs?* – There's clean water here so it makes a difference.

2	Child justifies choice by uncontrolled comparison of cases without recognition of alt. conclusions (**SRSI Q3 & Follow-up**)[a]	Here, number of factories is low and water is clean, over here number of factories is high and water is dirty. *Investigator – How do you know it is recycled water and not one of these other things that also differs?* – Because when there are lots of factories, they give off lots of pollution and that will make the water dirtier.
3	Child justifies choice by uncontrolled comparison, but with recognition of alt. conclusions. (**SRSI Q3 & Follow-up**)[a]	If you look here, this city has lots of pets and the water is clean, and here there is not a lot of pets and the water is dirty. *Investigator – How do you know it is number of pets and not one of these other things that also differs?* – It could be also be recycled water because that is going up too.
4	Child justifies choice by controlled comparison of cases, but with inconsistent interpretation. (**SRSI Q3 & Q6**)[a]	Over here, there is a lot of factories, and water is dirty, and over there is not a lot of factories and nothing else is different and the water is clean. So lots of factories makes a difference. *Investigator – what if this city had less factories* – the water would be cleaner. *Investigator -If someone told you they were going to clean up factories to make the water cleaner what would you say?* – I would say that is a bad idea.

5	Child justifies choice by controlled comparison of cases, with consistent interpretation. (**SRSI Q3 & Q6**)[a]	Over here, there is a lot of factories, and water is dirty, and over there is not a lot of factories and nothing else is different and the water is clean. So lots of factories makes a difference. *Investigator – what if this city had less factories* – the water would be cleaner. *Investigator -If someone told you they were going to deal with the factories to make the water cleaner what would you say?* – I would say that is a good idea, it would help make the water cleaner.

[a]The critical interview item(s) for coding each scientific reasoning level.